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FACTS AND OPINIONS.

REGARDING THE ECONOMICAL CONSTRUCTION AND WORKING

OF

RAILWAYS

OF

NARROW GAUGE

WITH

STEEP GRADIENTS AND SHARP CURVES

WHEN

WORKED WITH AN IMPROVED CLASS OF

ENGINE AND ROLLING STOCK

COLLECTED

BY

THE P. W. D.

CENTRAL PROVINCES

JUNE 1879

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PREFACE.

This little pamphlet has no claim whatever to originality, as the contents prove, how it came to be printed I shall explain.

When the Government of India determined to undertake the construction of the railways of the future in this country, my attention and that of other Engineers in the Department in the Central Provinces (who like myself had been formerly engaged on railway works in Europe) was naturally directed to the consideration, of the various and important changes which of late years have taken place in the construction of Railways, with a view to economy in construction and working; and also to improvements in engines and Rolling stock.

The result has been, that from various sources, valuable facts, and data, were collected having regard to the cheap construction and working of these communications in various parts of the world; but the information thus gained was so scattered through various publications, that it required some time and trouble to refer to it, I therefore collected a few of the more important facts and have had them printed for ready reference.

To give the latest and best opinion on the general state of feeling in England with regard to railways; I place first those valuable and remarkable articles on the "Railway Problem" and the "Railways of the future," which have appeared lately in "*The Times*," as also an article on the

latter subject, published in the "*Railway News*,"—The facts and opinions stated in these articles, are full of interest and instruction.

In the second part of this little pamphlet will be found the report of the results of the experiments on the Festiniog Railway with a Fairlie engine, the gauge being 1 ft. 11½ inches; and also the report of experiments made on the 4 ft. 8½ inches gauge with Fairlie's Engines the lines being the Mid Wales and Brecon and Merthyr.

In addition descriptions are given of the constuction, and rolling stock of many of the lines recently constructed in England, Prussia, Belgium, Norway, Queens-land, Chili. The Mauritus &c., as well as a list of the most remarkable of the steep gradients which exist on some of the older lines in many countries.

These facts have been gleaned from the pages of certain Engineering Papers and also from the "Proceedings of the Institution of Civil Engineers." The latter are not published for general use but for Members and Assosiates of the Institution. They are valuable not only on that account but specially so, because they only record facts Illustrating and referring to works actually constructed, and which admit of no dispute as to practicability of execution and so on.

The general result will be found to be, that of late years Lines of Railway of a narrower gauge than 4ft. 8½ inches, have been constructed at a reduced cost, and with much steeper gradients and sharper curves, than not long since were believed to be unadvisable if not impracticable,—such Railways by the use of an improved description of engine and Rolling stock, can at a lower rate for working expenses do

the same work as the original lines of 4ft. 8½ gauge with easy gradients and half or ¾ mile curves.

Mesrs. O'Callaghan and Binnie Executive Engineers have assisted me in collecting the information given in the following pages, we do not pretend to be authors and our time is not our own, but if we had had some leisure, we could readily have produced a Pamphlet more complete, and embracing more details; one which would have entered into the cost and advantages of the Indian Railways of the Future, if constructed on the principles recommended in the following articles and statements.

I hope some Engineer who may possess spare hours will take up this question.

T. W. ARMSTRONG, M. INST. C. E.

NAGPORE,
June 1870.

NOTE.- Since the above was written and this little Pamphlet was in the Press the Government of India Circular No. 5, Railway and its enclosures have been received. I think however that the facts and opinions I have had printed will still give some useful information.

T. W. A.

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PART I.

OPINIONS OF THE PRESS,

IN

ENGLAND

ON

"THE RAILWAY PROBLEM,"

AND

"THE RAILWAYS OF THE FUTURE."

CHAPTER I.

THE RAILWAY PROBLEM.

THE TIMES, OCTOBER 19, 20, 21, 1869.

NOTICE No. 1.—*Times of 19th October*, 1869.

Two prodigious statements have been made this year in regard to railways which are well calculated to strike the popular imagination, and to convey in a compendious form all that we know of railway mismanagement. The first is a statement made by Mr. Laing as to certain branch lines constructed for the Brighton Railway, that the shareholders who subscribed the capital of 4,000,000*l.* towards their construction might as well, for any benefit which can accrue to themselves, have taken bank notes to this amount and used them to light their pipes with. That is certainly a vivid description of the waste of money laid out in branch lines which can bring no return. It shows that there must be something radically wrong about them. The fact is that from the first we have spent too much money on railways; but this was excusable for a long time, since we had much to learn and had to pay dearly for our experience. But the waste which

was pardonable in our main lines became profligate when it was permitted in branch ones. There has been a wicked want of consideration, not indeed with respect to the localities into which these branches run, but as regards the cost which should be incurred in their construction. We need not stay to inquire into the motives which have led to so much waste; but we may point out in a few words how utterly indefensible has been the outlay. Let us imagine a trunk line of railway with eight or ten branches. The trunk line having cost, say 20,000*l.* a mile, has to carry over it not only its own traffic but that of the ten branches besides. Strange to say, the branch lines have in many cases cost more than the parent line, although it is but fair to assume that not one twentieth part of the traffic of the trunk could pass over the branch. How is it possible for these branches to pay? In the Isle of Wight some of the railways have cost 30,000*l.* a mile of single line, where it is not too much to say that the traffic, which is chiefly for pleasure, and therefore of a light character, might easily have been carried on railways of much slighter structure, that would have cost, including the rolling stock, no more than 5,000*l.* a mile. And now there is a cry for more and more railways and for more and more branches. Any one, indeed, who will take serious note of these demands all over the country must see that our railway system is not yet nearly completed. Innumerable roads have yet to be formed, and it is impossible that shareholders will subscribe to them if there is not to be some radical change in the conditions under which they are to be constructed and worked. It will not do to go on lighting pipes with millions of bank notes.

The other prodigious statement to which we have referred is one which Mr. Haughton, of the North-Western Rail-

way, made in a letter to ourselves the other day, though he is not alone responsible for it. Mr. Fairlie, in his paper read before the Society of Arts last year, Mr. Haughton, in his paper read before the Society of Civil Engineers, and Mr. Haggard, in his pamphlet entitled *A Mile of Railway*, proved very clearly that there is an enormous disproportion between the net and tare of train loads. In Mr. Haggard's pamphlet it is stated, on figures furnished by Mr. Haughton, that every passenger carried by rail weighs a ton; in other words, that supposing a passenger and his luggage to weigh in reality two hundred weight, the rolling stock which has to be set in motion in order to convey him to his destination multiplies his weight tenfold, so that for every passenger a ton has to be hauled. Mr. Haughton then corrected his figures, and in a letter addressed to ourselves as well as in his paper read to the Society of Civil Engineers, showed that every passenger weighs two tons; and Mr. Fairlie asserts that the calculation has to be still further corrected, for the actual weight of a passenger as carried by rail is not less than two tons and a quarter. In this last statement of the case Mr. Fairlie is confirmed by another Engineer, Mr. Samuel, who declares that for every ton of passengers the engine has to draw 33 tons of load, and who reckons the average real weight of a passenger at a hundredweight and a half, not as Mr. Haughton, at two hundred weight. In the goods trains the disproportion between the paying and the non-paying weights is not so extravagant, though it is great enough in all conscience. According to Mr. Haughton's calculation no more than 30 per cent. of the load which is hauled by a goods train represents paying weight; the remaining 70 per cent. is dead weight. Such a statement as this would of itself be astounding were it not eclipsed by the statement as to passenger trains that only five per cent. of the load

pays, according to Mr. Haughton, and only three per cent according to Messrs. Fairlie and Samuel, the remaining 95 or 97 per cent. being mere dead weight, without which it is said to be impossible to carry the poor little percentage of paying load. Let us think for a moment what this means. An ordinary omnibus may be assumed to weigh a ton, and its two horses, with their harness, are over-estimated at another ton. It carries 28 passengers, who, having little or no luggage, may be estimated at two tons. The paying and the non-paying loads thus balance each other. There is 50 per cent. of the one and 50 of the other. This is what occurs on ordinary roads where traction is difficult. What should we expect on the rail, where traction is easy? Is it not monstrous that the average dead weight of our passenger trains should, by the lowest reckoning, be 95 per cent. of the entire weight? that to compare the figures with those of the omnibus it is necessary for the carriage of two tons of passengers to set in motion, not as in the omnibus twice, but actually 20 times that weight of rolling stock and freight combined? or, to return to the succinct statement of Mr. Haughton, that every passenger should weigh two tons, and of Mr. Fairlie, that he should weigh two tons and a quarter? Surely there is a gigantic mistake somewhere. Surely this enormous waste of power cannot be necessary. Surely it must be a severe reproach to mechanical science, so long as a ton of passengers means, according to one calculation, 20 tons, or, according to another, 33 tons of load to be carried, and that not on rough ordinary roads, but on rails.

It is impossible to acquiesce in such a state of things, and the first thought which must cross one who reads of it is that the engineer who describes it is instantly going to pro-

pose, good or bad, some remedy. What is our amazement on reading Mr. Haughton's paper to find that remedy there is none? His paper is written to show that it is impossible to reduce railway fares. To the popular demand for reduction of fares he points out, truly enough, what an enormous work the locomotive has to perform. Every passenger behind the locomotive weighs a couple of tons, and how can people expect railway companies to lower the fares on such a load? If we argue that the amount of dead weight is excessive and must diminish as science improves, we are told by Mr. Haughton that, on the contrary, dead weight has been of late years on the increase, and that "by no known processes can those enormous multiplications of original net weights be reduced consistently with affording that amount of personal security and comfort and accommodation now eujoyed." If we are to accept this as the last result of engineering science there is certainly a bad look-out for the fares of passengers and for the dividends of shareholders. Mr. Haughton seems to regard it as the height of extravagance to look for benefit to either. Railways have certainly taught people to be extravagant. They have achieved such wonders that they have raised unbounded expectations. We hear of some worthy people, for example, able men, too, who at the last meeting of the British Association proposed that Government should take possession of all the railways in the kingdom, and should establish a uniform fare for all distances, say of a shilling for the first class, which would convey a passenger equally well from London to Greenwich and from London to Inverness. These are wild dreams; but surely not less wild is the dream of the satisfied engineer who tells us that the enormous waste of power expended on our railway trains is natural and inevitable, and that by no known processes can we improve upon the present state of things. If Mr. Raphael Brandon, who

imagines that he can travel from London to Inverness for a shilling, be a dreamer of the first magnitude, surely he is not less a dreamer who is so wedded to the established order of things that he cannot conceive of any process by which the present prodigious waste of power on railways can be diminished without affecting the safety and the comfort of passengers. Mr. Haughton and others quote a little too freely, using as a kind of proverb the statement of *The Times* that we have here in England "the best-served travelling community in the world." Does it follow that this community of travellers cannot be better served, that the not less important community of shareholders cannot also be better served, and that, in a word, we have reached the final result—the *ne plus ultra* of railway engineering? It is astounding to find an engineer of Mr. Haughton's ability and position first of all prove that not 5 per cent. of the load of a passenger train is paying weight, and then proceed to the expression of his belief that his countrymen when "made aware of the actual condition of affairs will accept it as being on the whole the best possible," inasmuch as "the railways of the United Kingdom are conducted by an accomplished, scientific, and highly skilled body of experts who know their business, do it, and don't talk about it, and who, moreover, take out of the locomotive all they can and present it freely and *exuberantly* to those whom it is their interest as well as their pleasure to accommodate—the travelling community."

It is now about 20 years since an outcry began to be raised unheeded against the extravagant system of our railways. Our present railway system was established in all its vigour in 1845-1846. Three years afterwards an engineer of some eminence, Professor Gordon, in a pamphlet on *Railway Economy*, put forth this criticism, which was little heeded

at the time, but has since become almost common place :—

"The existing railway machinery will be found monstrously disproportionate to the useful effect produced in four-fifths of the number of times that the machine is put in action. And to this waste of power may be most justly attributed much of the present embarrassment of railway companies."

Again, in another passage, he wrote :—

"These figures indicate the small portion of the mechanism of the railway system of transport that is actually brought into requisition, even on the most frequented lines. Thousands, nay, millions of miles are run by locomotives and carriages on the present system, while they are performing an amount of transport of passengers preposterously disproportioned to the power and capacity of the trains employed for effecting it."

The protest thus raised has been gradually coming to a head, until at length, in spite of what Mr. Haughton says as to impossibilities, it has been forced upon the public mind that something must and can be done ; and we propose to-day to direct attention to the solution of the difficulty proposed by the engineer who in this country has been foremost in insisting on the necessity of lightening the structure of future railways, and of lightening even while increasing the work of the railways which exist. Mr. Fairlie has long been at work on this question, urging his views in many ways, but he has recently been able to carry out his designs and to show them in full working order, and the result has been so remarkable that for some weeks past the railway and engineering journals have been constantly engaged in discussion of their merits. Whatever be the result of this discussion, whether to confirm Mr. Fairlie's calculations or to tone them down or entirely to upset them, the question at issue is so important and occupies so much attention that it is right to set

the leading facts and arguments clearly before the public, leaving them as far as possible to form their own conclusions. In so doing, we shall endeavour to avoid technical details and language, and to state the case in plain English for ordinary readers.

First of all, then, let us state that Mr. Fairlie is now exhibiting at the Iron Works at Hatcham a steam carriage which goes through a surprising performance. The carriage is 43ft. long; and yet it is driven at the rate of 20 miles an hour on a line of rails laid in a small cabbage garden of about half an acre in extent. It whisks round curves of 50ft. radius with perfect ease, with scarcely any noise, and without the slightest danger. If the curves had been still sharper—say of 25ft. radius, the engineer declares that his carriage could curl round them with not less ease, and, if possible, with even greater assurance of safety. The result thus obtained is very striking and full of interest to all who care to study the question of railways; but we should state at once that we give it the first place in the record of what Mr. Fairlie has attempted, not because the means by which these sharp curves are rendered practicable are wholly of his invention, but because they lie at the base of whatever subsequent improvements in the construction of rolling-stock he has been able to suggest. An ordinary train cannot pass round sharp curves, because the carriages have a rigid wheel base, of considerable length. Get rid of this rigidity, and we can make the carriages turn. Every one knows how an ordinary four-wheeled carriage is made to turn sharp round on an ordinary road. It is because the front wheels are not rigidly attached to the carriage, but have a horizontal movement underneath it and independent of it. Now, if we imagine a carriage in which the wheels behind have a horizontal movement similar

to that of the front wheels, we shall have a very fair model of what is known in the railway world as a "bogie-carriage," and can understand the principle on which Mr. Fairlie works. "Bogie" is a north-country word for a spirit, a goblin, the devil; and bogie carriages were first used many years ago in Newcastle, where it was necessary for the coal waggons to double about the quays. They were so named because they were supposed to turn upon one like a spirit, and to face one when least expected. You saw a bogie-carriage going off in a particular direction in full force; in a moment it wheeled round an unexpected curve and was down upon you. "It's Bogie himself," cried the miners; and so the waggon was named. The waggon, instead of being supported on four wheels rigidly combined in the same or parallel planes, was placed on two small but strong trucks, called bogies, which represent the front and hind wheels of the ordinary carriage to which we have referred. Each of these trucks may be supported on one, two or three pair of wheels, according to the size and strength required, and in the *centre* of each is a pivot—the bogie pin, as it is called—on which the coal waggon rests. The advantage of the system is that it wheels can encounter a very rapid curve of rails, because they are not locked into the system of a rigid wheel base belonging to the whole waggon. Each of the small trucks under the waggon is independent, and the engineer who has to calculate the curves of his line has in effect to calculate curves for the passage not of enormous waggons, but of small trucks on which the waggons are poised. The system worked so well at Newcastle that it was adopted in America as best suited to the rude roads of so vast an extent of country, and admirably has it served them, making the traffic easy where, without such carriages, it would be very rough and difficult. And now Mr. Fairlie has adopted this system of poising a

carriage upon wheels as the basis of all the improvements which he suggests in the construction of rolling stock, and in particular as the basis of his scheme for light railways. In testimony of its success he shows, as we have said, a passenger train in working order, careering at 20 miles an hour round a small cabbage garden. It is important to make this demonstration, because if railways are to advance we may be sure that many sharp turns are in store for them. To avoid these sharp turns both in town and country most expensive tunnellings, cuttings, and viaducts have been undertaken, which in the new order of things, fast coming, will no more be tolerated. The rail must be taught to double round a street corner or a steep hill; and in the garden at Hatcham we are shown how this may be done. Most people who have gone to Paris have made a trip to Sceaux, and seen the singularly ingenious contrivance by which the train is made to turn round at the Sceaux station so as almost to take the form of a serpent biting its tail. That is a complicated contrivance unfit for general use. At Hatcham we become acquainted with a simple device which may be used and is used on the roughest roads, and at great velocities.

So far we give Mr. Fairlie no credit for originality, and he claims none, as we understand. He has merely adopted an arrangement which he found ready to his hand, but which he sees more clearly than others to be of immense use in the future of railways, and which he has turned to account with singular ingenuity. Mainly through his urgency it is becoming accepted among our engineers that there is no mode of traction for railways so easy and so convenient as that afforded by the bogie, which has been long adopted in America; and, indeed, without it the American system of railways could never have been established. The long cars used on

the American railways, for example, would be impossible without the bogie; and the bogie, as we have already hinted, has helped to give ease and stability to the motion of trains on rough roads, where, without it, the jolting would have been terrible. It may be worth while to explain this in a few words—for the point is of importance as a contribution to the theory of light and cheap railways, and we shall have to refer to it again and again. A railway carriage or waggon poised directly upon wheels, as usual in this country, is a load supported on two points towards the ends of the different axles in use. Let us for the sake of simplicity fix our attention on a single axle. The superincumbent weight rests at each end of the axle tree within the wheels; as the carriage is in motion there comes a rough bit of road and a jolt; the carriage is jerked on one side, and its weight comes down on the other with a blow which, despite the carriage spring through which it passes, must ultimately tell on the rail underneath. The rail has not only to bear the share of load which each wheel conveys to it, but that load is increased with the jolting as by the blow of a hammer. The carriage then rights itself, and in the process jolts back to the other wheel, which in like manner conveys the force of a heavy blow to the rail. So the carriage oscillates with the force of a hammer from side to side until the oscillations gradually die away, and a new series of oscillations with consequent blows succeed at the next bit of rough road. All this hammering adds greatly to the destruction of the permanent way. And how is it avoided or lessened by the use of bogies? It is so, because the load—be it a carriage for passengers or a waggon for goods—is poised on pivots in the centres of two bogies. The load rests on two points which follow a line midway between the rails. There may ensue from this some slight oscillation of the carriage; but it is not an oscillation which hammers alternately on the

wheels, and which can disturb to any great extent the centre of gravity. The centre of gravity is maintained in the centre of the line, so that the shock from side to side is reduced to a *minimum*, the comfort of passengers is promoted, and much tear and wear of rails is prevented. The point is well worthy of notice, because, in fact, we here touch upon the chief advantage of the bogie. The most obvious advantage of the bogie is that of quick turning, from which it derives its name. It renders practicable to trains the most rapid curves, and curves of an intricacy which, according to the system now in vogue among us, it would be madness to attempt. But if its power of adopting itself to curves constitutes its most obvious and showy characteristic, its most important characteristic, and that which most of all recommends it to the engineer who seeks to solve the mighty problem of railways, is the power which it possesses of adjusting and equalizing the load upon wheels, and of steadying the train. It is a matter of no little importance that on the railways of the future we should be able to turn about in a small space, and bogie is, indeed, a good bogie that will help us to such an achievement. But bogie is most of all a good and clever bogie if it will lighten our load and make it easy, like the lubber fiend of the fairy tales that works for us of his own good will. And it is to this power possessed by the bogie of adjusting, equalizing, and easing a load that we are now chiefly to turn our attention in discussing the problem of railways.

Before entering into this discussion, however, and showing how Mr. Fairlie brings the bogie to bear upon it to solve the railway problem, it may be well to complete what has to be said of the bogie, as applied to curves. In travelling round swift curves it is found that both the existing system of coupling carriages and the existing system of buffers are

seriously at fault, endangering the stability of the train, and damaging the rails and rolling stock. Everybody knows the accepted system of buffers. These are placed two and two at the extreme ends of the carriages or waggons, right and left. Now, if we place two carriages, end to end, upon a sharp curve, it must be evident that, since the carriages represent two rigid straight lines, the buffers on the inner side of the curve will be in close contact, while those on the outer side will be far apart. But if this state of things exists on the level of the buffers, there must be a corresponding condition of things on the level of the wheels. The flanges of the inner wheels will be relieved from the rails, while those of the outer set, which are already from centrifugal force too much inclined in that direction, are pressing hard against them and grinding them to destruction. Another result also follows. In order to permit a state of things by which the buffers on one side of two contiguous carriages shall be pressed together while those on the other side are far apart, the coupling chains of the two carriages must be loose, and from loose coupling arises the concussion of carriages with which we are all familiar. Passenger carriages on straight lines are generally coupled so as to jam the bufferheads together. The carriages run much more steadily when so coupled, the oscillations produced from great speed are diminished, and the severe jerks and collisions which we have all felt at the starting or the stopping of a train are prevented. In lines of much curvature it is impossible to have this tight coupling, and hence much knocking, bumping, discomfort, and breakage. Besides which, on goods' waggons and cattle trucks it is impossible, in almost any case, to have tight coupling, and hence much damage to goods and much suffering to the cattle; hence, also, the necessity of making these waggons stronger and heavier than they need be in order to resist the

force of frequent concussions. Get rid of the buffers altogether and couple the carriages close, says Mr. Fairlie, and you will get rid of these concussions. "It is well known," he says, "that nothing is so beautifully delicate in its movement as an engine passing from rest into motion. Those who may have stood on the footplate and started an engine, even without a train, know that it is done in the most easy and graceful manner. Therefore, by coupling up the train *in one solid mass,* its movement must be as delicate as that of the engine itself, and all the damaging effects of the present system" are obviated. But how is this to be done, at the same time providing for the flexibility of the train? The ends of the carriages and waggons at present meet each other square. Mr. Fairlie proposes, in the first place, that these carriages, where they meet, should present to each other a circular front. This would give them, instead of, as at present, in the buffers, two points of contact, the positions of which are invariable, a single point of contact, the position of which would be variable. If the carriages are in a straight line, they will touch in the apex of the curves which they present to each other. If they meet each other at an angle a new point of contact will be formed upon the curve to right or left of that apex. But for this purpose the carriages must be coupled after a new method. According to the present method, the coupling chains or bars hold on to the ends of the carriages—from points on the middle of the ends. But this arrangement is obviously impossible if, as Mr. Fairlie proposes, the carriages constructed with curvilinear ends are to meet normally in the middle of these curves, and are to have free play to move round each other from side to side. It is, therefore, proposed that the junction of carriages shall be effected not between the ends where they meet, but by a draw-bar passing underneath the carriages from centre to centre. Whichever way the carriages

may turn, this drawbar, being made up of two radii of two circles which are in contact, must always be of equal length.

The advantage, however, of this method of coupling the carriages is not merely that it prevents concussion by screwing up the train in one solid, but flexible mass, that carriages and waggons, therefore, saved from the ills of concussion may henceforth be built somewhat lighter, or may be expected to last longer, and that the flange friction of the wheels upon the rails is much diminished, but furthermore the traction of a train upon curves becomes easier and safer. This may readily be explained if we give our attention to a single carriage of the ordinary construction, and imagine it as a straight line. Imagine this straight line—that is, the carriage—placed upon a curve which represents an imaginary line midway between the rails. The straight line will be a tangent to the curve. Its midpoint, which represents the centre of the carriage, will touch the curve which represents the centre of the road ; but its two ends will be off the curve and outside it. There must evidently be a considerable difference if the force of traction exerted upon this carriage seizes the centre, which keeps to the centre of the road, or seizes the end which is off the road, and has an increasing tendency to fly furthes and further off. If, now, we imagine the carriage represented by a line, not as one of the usual construction, but as one resting on bogies, and if we place these bogies represented by the two ends of the carriage line upon the curve, the line of the carriage will no longer be a tangent, it will be the chord of an are, and, its midpoint being always within the curve, the force of traction exerted upon it will be directed to pull the carriages inwards, and so to diminish the friction upon the outer rails, and to preserve the centre of gravity always on the safe side.

But in all this the prominent fact to be seized is that the primary object of the engineer is to ease the rail, to steady the train, and in the end to lighten the load. That question of the management of curves is of subsidiary importance, and, though interesting in itself, it is chiefly interesting as showing the capability of the bogie to solve the problem of easing the rail under the most difficult conditions. Mr. Fairlie, as we have just seen, has struggled with one part of this problem in dealing with the mode of coupling carriages, and their traction. We have now to consider what is most peculiar to his system, and how he proposes to work out such results that, whereas, according to Mr. Haughton, every passenger now carried weighs on the average two tons, that is 40 cwt., and whereas, according to Mr. Samuel and Mr. Fairlie himself, every such passenger weighs 45 cwt., he undertakes that they shall weigh no more than 5 cwt. It has already been sufficiently indicated that he proposes to work this ont by means of the bogie. What is peculiar to his use of the bogie is that, having great faith in it generally, he for the first time has ventured to apply it to the driving wheels of the locomotive Before him the bogie was in use as applied to carriages, cars, and waggons, and occasionally to the carrying wheels of the engine; but he has now applied it to all the wheels of the engine, and has certainly got out of it results which are worthy of consideration. The first result, however, is not perhaps that which readers will expect who may bear in mind the earlier paragraphs of this article, in which we laid stress on the need of light railways, and in which we described the light steam carriage in the garden at Hatcham. The first result is the production of locomotives much more powerful than any which have yet been built, and yet much more economical as regards wear and tear of the permanent way and their own wear and tear. Mr. Kittle,

the eminent engineer of the Midland Raiway, has taken the initative in placing one of these double bogie engines to work the heavy coal traffic at the London end of his line. The grand principle of the bogie is that it distributes, economizes, and eases the load. Therefore it not only makes extremely light railways possible, but it also makes extremely heavy ones more manageable than they ever were before. Now, as heavy railways are in existence, and the light ones are in great measure still to come, the problem of the former is even more imminent than that of the latter, for Mr. Fairlie's theory is that passenger trains on all railways should be much lighter than they now are, and that goods trains should be much heavier. And not only is the question of how to deal with heavy traffic more pressing than that which concerns light, but also in examining how the bogie can be turned to account in the solution of the heavy problem we can see its working more clearly and fully than in the case of light railways. Let us examine the question, therefore, first of all as appertaining to heavy loads on existing railways.

THE RAILWAY PROBLEM.

NOTICE No. 2.—*Times of 20th October*, 1869.

For heavy goods traffic heavy locomotives are used; but those of the current type have two faults:—They eat up the rails, and their strength is limited.

With regard to the first of these faults it is to be noted that the chief destroyer of the rails is the locomotive. The carriages and waggons are comparatively innocent. It is for the monster engines that year by year engineers are laying down stronger and stronger rails of steel, and still find the greatest difficulty in repairing their ravages. The engineer of the permanent way is in despair for the means of keeping his line in order. Go to him and he will tell you,—"We carry millions of tons of goods on our line, but we might carry as many millions without hurt were it not for So-and-so's engines. They tremble and grind along, and break down all before them. What should remain a perfect road for years with not more than two men to the mile to look after it is now hammered out in as many months, with five times the number of men employed upon it." We have all heard of the great war which is now gofng on between armour-plate and guns. There is a similar war carried on between the locomotive and the rail. The railway engineer swears against the ponderous locomotive floundering over his road and crushing it to pieces; while the locomotive superintendent swears against the bad roads that wear out the tyres and axleboxes,

and breaks the springs of his engines, so that it is as much as he can do to keep the stock on the road at all. It is to be observed, however, that this process of mutual destruction is not produced by the normal weight of the engine. It is produced by the hammering which comes of imperfect equilibrium. Will our readers be good enough to recall what we attempted to show as to the jumping of an ordinary carriage upon the rails? It is the same with the ordinary locomotive. Poised in a similar manner upon its wheels it rocks from side to side till it bends the rails into a crook like a dog's hind leg, and there are many instances in which the strongest steel rails have to be taken up and replaced in six months. It is calculated that the blows produced by the violent oscillation of a locomotive going at 30 miles an hour may be taken at 60 per cent. added to the weight upon the wheels. If the nominal weight upon the wheel of a locomotive is eight tons, then the momentum of concussion may be taken as raising the weight to more than 12 tons. It is in view of such a tremendous system of destruction not only for the rails but also for the machines which roll upon them that Mr. Fairlie comes forward with his bogie notion. Even before him it was deemed advisable by several engineers who were satisfied of the good effect of the bogie to rest the locomotive upon one; that is to say, one end of the machine was made to rest upon a bogie while the other end was sustained in the usual manner upon axles. By this means the oscillations were diminished, but they could not be entirely removed and the locomotive made quite steady, while at one end the load was so arranged upon axles and wheels that there was a see-saw movement from side to side, coming down upon each pair of wheels with a violent shock. If the oscillation is to be entirely dissipated, there must be a complete surrender to the principle of the bogie. Mr. Fairlie, for the first time, laid

the locomotive on a pair of bogies—making even its driving as well as its carrying wheels the wheels of bogies. He has in this way been so successful in getting rid of violent and destructive oscillation that Captain Tyler, the Government Inspector, declares of one of the Fairlie engines on which he travelled at a speed of 50 miles an hour, that it was absolutely free from oscillation, and that its motion was so smooth as to be comparable only to flying.

The other fault, which we imputed to the current type of engine, is that of weakness—of course, comparative weakness. On some of the lines there is an enormous amount of work to be done in the carriage of goods and minerals. The roads are blocked with the trains, so that on the North-Western Railway they have to resort to the costly expedient of tripling the line. The train loads have been gradually increasing, till now it would seem that according to the system in vogue we can go no further. There was a time when the load of 100 tons was considered a great thing; now loads of 300 and 400 tons are an every day occurrence. But the locomotives which are used for these huge loads are, as we have seen, ruinous to the permanent way, and yet they cannot clear off the traffic fast enough. Mr. Fairlie cries aloud to the railway companies:—"Your passenger trains are ten times too heavy, and your goods trains are only half what they ought to be. There is no reason why, by adding several hundred tons to each of them, you should not reduce by one-half the number of your goods trains, which now block the way and create so many accidents." The answer to this is, that, as a matter of fact, we have kept on increasing the loads until at last we have reached the limit of endurance of the rails, and that, as regards the locomotives, we have gone on piling weight upon weight and increasing them in length and

breadth and height until now we have come to a standstill. We cannot increase them in length, because of the rigid wheel-base, which now so much exceeds what it should be that, notwithstanding the very heavy rails employed, it takes more than three times the number of men per mile to repair the line and to keep it in guage than it used to do a few years ago. We cannot increase them in breadth, as the guage is the limit to this. And we cannot well increase them in height, as the monsters now look like towers tearing along on wheels, and these wheels, with their vast superincumbent structures, are already overloaded, and in turn overload the rails. But here again strikes in Mr. Fairlie with his answer, which is that by adopting the bogie system of carriage in its entirety we can solve the problem, for we can adjust the weights of the locomotive more equably, we can move it with less disturbance, and we can increase its length without lengthening the wheel base. Accordingly, he has constructed several locomotives which are not heavier than heavy locomotives usually are, which have the load so distributed upon the wheels that upon any pair the pressure is not so severe as it is on some of the wheels of locomotives of the current type, and which, nevertheless, possess two boilers, with two pair of cylinders, capable of driving a goods train loaded to 800 tons. One of these locomotives, entitled Progress, is now employed on the Midland Railway, and at a public trial of its powers performed as follows :—There is between Hendon and Kentish-town a rising gradient of 1 in 180 for more than a mile. Up this gradient the locomotive hauled from 60 to 70 loaded coal-waggons, weighing 700 tons, at a speed of 15 miles an hour. The engine is only of medium size, according to this principal of construction, and yet it possesses about twice the power of the heaviest in ordinary use.

Mr. Haggard, in his well-known pamphlet, made a remarkable calculation. He stated that if but one penny a mile could be saved on all the miles of train run in the United Kingdom in the course of year there would be an additional sum of 618,000*l.* to distribute among the *ordinary* shareholders. The cost of running a goods train is on the average about 3s. a mile, while its gross earnings are about twice that sum; but suppose that you double the size of the goods trains, and therefore earn double, does it follow that you double the expenses? Nothing of the kind. One of the Fairlie engines, capable of performing double the task of an ordinary heavy engine, does not cost nearly double. The original price of the one may be set down at 2,500*l.*, that of the other at 3,500*l.* The fuel, oil, tallow, &c., which the one consumes is not nearly double the consumption of the other. It does not require anything like twice the number of men to attend to it. The locomotive laid upon bogies is even less destructive to the permanent way than the ordinary engine; and if the bogie principle could be adapted to the goods trucks, their wear and tear of the rails would also be diminished. Mr. Fairlie, as we understand, claims that the extra expense of the double-loaded goods train would be less than 1s. a mile, but probably this is a sanguine reckoning. Suppose we say 1s. 6d. a mile. Still there is a tempting profit left which is worth grasping at. It is calculated from the last railway returns that the average earnings of a goods train on our best lines are, as we have said, about 10s. a mile and that its expenses are about half this sum. If trains could be doubled, the average earnings of each would be 12s. a mile, while the expenses would be increased to less than 4s., as Mr. Fairlie maintains, but to be within the mark we say 4s. 6d. There remains on the transaction a clear gain by the new method of 1s. 6d. a mile for the dividends of shareholders. Besides which, by

having one train in place of two, the road is cleared, the risk of accident is diminished, and companies are saved the necessity of constructing at great expense a third line of rails. The system, it is clear, must be especially valuable to railways that possess but a single line.

If now we turn from the consideration of goods traffic and proceed to consider that of passengers, we find a very different state of things, with regard to which opinions vary not a little. On the one hand are Mr. Raphael Brandon, Sir John Bowring, and Dr. Farre crying out for a uniform fair of 1s., which will cover the cost of transit from London to John o'Groats, as well as from London to the Crystal Palace. On the other hand is Mr. Haughton, strenuously insisting on the impossibility of reducing railway fares, and declaring that engineers just now get the very most out of the locomotive, and present it freely and "exuberantly" to the passengers. On the onehand, again, there is Mr. Haggard, in his pamphlet insisting on the necessity of reducing the number of trains in a day; on the other hand, are his critics (ourselves among them) protesting loudly against any such reduction. But at the basis of all that has to be considered there lies the fact, which cannot be too often repeated, that a ton of passengers involves, according to Mr. Haughton's calculations, a train load of 20 tons, and according to Mr. Samual and Mr. Fairlie, a train load of 33 tons. It is impossible to persuade us, as Mr Haughton thinks we can be persuaded, to accept such a state of things "as under the circumstances, the best that is possible." And we cannot help regarding with some interest Mr. Fairlie's statistics when he assures us that it is quite within the reach of engineering science to carry passengers in such a manner that each one in the train shall count only for five hundredweight of load, and not for the 40 hundred-

weight which, according to Mr. Haughton, they at present involve. In putting the comparison thus, however, it is open to misconstruction, for by a passenger Mr. Haughton understands an average weight of two hundredweight, counting luggage; while Mr. Fairlie, taken note of the millions and millions of passengers who makes excursions without any luggage whatever, insists that a hundredweight and a half, or 12 stone, is a fair average figure at which to rate the passenger. The comparison may perhaps, therefore, be better rendered by saying that whereas Mr. Haughton declares that a ton of passengers weighs in a train no less than 20 tons, and whereas others declare that it weighs no less than 33 tons, Mr. Fairlie asserts that it is quite within the reach of engineering science to make it weigh no more than four tons. And, *primâ facie*, it must be admitted that the presumption is all in favour of Mr. Fairlie. If we take an omnibus working on rough ordinary roads and find that its two tons of passengers weigh no more than four tons in the entire weight of omnibus, horses, and passengers put together, then it is more natural to believe that on easygoing rails, even at an increase of speed, a ton of passengers should weigh four tons than that it should weigh 20. In urging this comparison, however, we have still to beware of error. For it is to be observed that when in the existing system of railways a ton of passengers is described as weighing in the train load 20 tons according to one calculation, and 33 according to another, this is an average, into which there entires the fact that many thousands of trains are never loaded to the full, and that indeed very many of them take a load of passengers one way, and then run back empty for another load. On the other hand, when Mr. Fairlie states that according to his system a ton of passengers makes no more than four tons of train load, he assumes that his train carries its full complement of

passengers. In the actual working of such a line as he imagines, the passengers must often be much less than the train can accommodate, the result of which is that when the time comes to strike the average for the entire year it will be found that the weight of trainload hauled is considerably more than four times the weight of passengers hauled. But no matter. Say the train load were double what Mr. Fairlie imagines, the gain which his system seems to promise ought to touch the hearts of shareholders, and is well worth considering.

How the scheme will work is shown in the small cabbage garden at Hatcham, to which we now return. This garden has been visited in the last few weeks by thousands of persons—engineers, directors, shareholders, and inquisitive travellers—who are interested in railways, and who have now the opportunity of judging for themselves what can be done. The carriage exhibited may best be described as a steam coach, with compartments, as in an ordinary railway carriage, capable of holding 66 passengers with the usual comfort, and weighing when fully loaded, about 18½ tons. With regard to the number of passengers which it can accommodate it should be stated that according to the railway returns for 1867 (the last published) the average number of passengers to a train, taking into account the immense excursion trains all over the kingdom, is 73. Therefore this combined engine and carriage, in proving for 66 passengers, makes room for very nearly the average number. Mr. Fairlie has designed another steam carriage on the same plan, which is not exhibited, but which has accommodation for 90 passengers, and, when fully loaded, weighs no more than 20 tons. If still more room is required nothing would be easier than to add on another carriage. The length of the carriage is 43 feet, including a compartment near the engine for the guard. The carriage at one end rests on a four-wheeled bogie which it has all to

itself. At the other end it rests another four-wheeled bogie, which, however, it shares with the engine. The bogies upon which it swivels have a wheel base of less than six feet, and, therefore, despite the great length of the carriage it can be drawn upon any curves which are fit for a wheel base of six feet in length to run upon. Actually on this garden the carriage passes round curves of 50 feet radius and it could easily go round one of 25 feet radious—that is, little more than the diameter of a good-sized turntable. Moreove, although the rails are laid round the garden in a rough and ready fashion, so as to have no pretensions to such smoothness as English travellers are accustomed to, the motion of the carriage—travelling round exceptional curves on a rough laid road—is easier than that of an ordinary train. Those who doubt can go and see. For the rest we quote from one of the technical journals—*Engineering*—some figures which may be interesting to those who wish to search deeper into the action of the new carriage. We confess to some bewilderment at the columns and columns of figures about this carriage which have appeared in every one of the engineering, mechanical, and railway journals, by all of which, indeed, the new comer seems to be hailed as a godsend. Those which follow are very simple, and may easily be apprehended by readers of ordinary intelligence. After pointing out that the steam carriage is 18½ tons, the writer goes on to say :—

"The adhesive weight is nearly half as much, and the average steam tractive force at least half a ton. The resistance of such a carriage at 25 miles an hour, upon a level would not exceed 300lb. or 400lb., nor, upon a gradient of 1 in 60, more than from 1,050lb. to 1,150lb., the whole actual work done being, say, 25 horse power in one case and 75 in the other, or, supposing the speed on the gradient to be diminished to 17 miles an hour, to but 50 horse power. The carriage is not one of the omnibus kind, but has seven compartments and a guard's van, in

all respects in conformity with the standard rolling stock of English lines. The weight per wheel being in no case greater than 2½ tons, lines of corresponding lightness would serve as well as heavy lines now serve for heavy engines, loaded as they are from 5, 6, 7, to even 8 tons upon each driving wheel. If even half filled with passengers, such a carriage at oridinary fares would earn about 5s. per mile, and if filled, of course twice as much. The whole cost of working would certainly be small. When working upon moderately easy gradients the consumption of coal would run but from 6lb. to 8lb. per mile, the wages of driver, stoker, and guard, making 100 miles a day, to but 1¾d. per mile, and repairs to probably less than a pound a day, or 2¼d. per mile, these respective expenses being thus only 5d. or say 6d. per mile, including all train charges. Permanent way, station expenses, and general charges might carry the whole to 1s. or 1s. 3d., but even at twice the last-named cost there would be a high proportion of profit on the work."

We have already observed that a statement which appeared in *The Times*, to the effect that the English is the best served travelling community in the world, has been quoted a little too freely by the apologists of the existing system of management. But, on the other hand, a parallel statement made in these columns, to the effect that the cry of the railway economists for a diminution in the number of trains is a demand to which the public cannot submit, has also been freely quoted as an evidence of the unreasionable expectations of this travelling community. The advocates of economy show clearly enough that some trains are crowded, that others are but half filled, and that again others are nearly empty; and they also show that it would be a gain to the railways not to run these little-used trains. But we have to look at the question from the point of view of the public, and we honestly think that for their accommodation, the trains run are by no means too numerous. If, being so numerous, they are too expensive for the railway companies, we maintain that this is their own fault, and the figures prove it. Say

what Mr. Haughton will, we cannot be made to belive this to be the last result of our boasted engineering science—that a ton of passengers must weigh on the average 20 or it may be, 33 tons. Instead of sending 73 passengers, the average number, in a train weighing 150 tons, why not try to send them as Mr. Fairlie proposes, in a train which, when fully loaded, is no more than 20 tons? Mr. Fairlie may be over-sanguine in his calculations, but at least he is grappling with the problem of railway economies at its right end, and his claims are worthy of a fair trial. If he can do half what he undertakes he will deserve our thanks.

A light train does not necessarily imply a light railway. The foregoing remarks, therefore, on the need which exists to lighten our passenger trains and the method of so doing apply equally to heavy and to light railways. But it is not possible to bring this discussion to a close without insisting on the necessity of lightning the construction of future railways. It is lamentable to think of the waste of money in our branch lines through thinly-peopled districts, and in our colonies, where there is great demand for railways, and where the engineers are proposing to build them on a magnificent scale. Our people have now become so accustomed to the railway that all over the country they sigh for its advantages, and there is nothing to stop them from projecting line after line but the enormous expenses which engineers, lawyers, contractors, and directors in combination declare to be essential to their construction. Why, when a little branch railway is to be constructed, engineers, contractors, lawyers, and directors should combine to say that it must be a grand affair is best known to themselves. We only know that this game has now been played out, and that if we are really to go on building more and more railways in this country it can only be on the

condition of their showing in the estimates and in the actual working a set of figures to which our railway kings are little accustomed, and which, perhaps, they might think it scorn to read—figures like those of the little Welsh railway which, built at a cost originally of 2,000*l.* a mile, has yielded to its shareholders a sweet little dividend of 30 per cent. 2,000*l.* a mile for a railway—can anything be more contemptible? Yet perhaps even railway kings may stoop to such meanness for the sake of the dividend returned. In the case of the little Welsh railway to which we have referred—one of 14 miles, between Festiniog and Portmadoc—the returns are 30 per cent. upon its original capital of 36,000*l.*, but as in the course of years 50,000*l.* has been taken out of revenue, spent in improvements, and therefore, treated as so much additional capital laid out, the dividend paid upon this total amount of capital, 86,000*l.*, is about 12½ per cent., and the line is still improving.

For one thing in future railways, the cost of land is immensely diminished. Time was when the land had to be purchased at exorbitant prices, and when directors, indeed, had to fight proprietors in Parliament for possession of it. Now, the owners of land are in many cases willing to give it freely for the sake of the advantages returned to them by the railway passing through their estates. And that goes far to diminish henceforth the average of 35,000*l.* a mile which our railways have cost. It will be diminished still further by lightness of construction in the permanent way and by consequent lightness of rolling stock. The lightness and cheapness of the permanent way depend upon several conditions, of which the first and most obvious is that it shall not be constructed as if it had to bear the weight of a colossal traffic when the traffic is as slender as it can well be. On this point

it is needless to enlarge. Nor yet on another point on which we have already said enough is it needful to dwell—namely, on freedom from the expense of deep cuttings, tunnellings, and costly viaducts through the necessity of avoiding curvature and keeping the train in as straight a line as possible. Following the bogie method of swinging the carriages, there is no amount of likely curvature in a road which the railroad need shun. It is not merely, however, to avoid curvature that in railways of the heavy existing type the great expense of deep cuttings, magnificent viaducts, and tunnellings has been incurred. It has also been incurred to avoid steep gradients, since, according to the present system of weighting the wheels of a locomotive, it was impossible to find adhesion enough for the driving wheels. By the use of the bogie and the readjustment and increase of weight which it renders possible, the adhesion of the driving wheels is so increased that Mr. Fairlie and his followers claim for the double-bogie engine the power of doing all the traffic up such a line as the Mout Cenis Railway, ascending the gradients of 1 in 12 with its own natural power of adhesion to the rails, and without the artificial adhesion created by the central rail. We quote such a statement, of course, with all due reserve, and with some doubt whether the engineers who exclaim against the necessity of producing artificial adhesion on a midrail on a gradient of 1 in 12 make sufficient allowance for the influence of climate upon the adhesion of their engines. What are the chances, for example, of slipping in the near proximity to Alpine cold? The statement, however, having been advanced, it may deserve to be quoted for what it is worth; and the more so seeing that, as a matter of fact, there is proof enough that the double-bogie engine does admit of greater adhesion, and therefore of easier ascension upon steep gradients, than the ordinary locomotive.

From these conditions necessary to the existence of cheap railways—namely lightness of construction, with great possibilities of curvature and of gradients—we pass on to another which may or may not be of much practical importance—it is difficult to say; but which, in connexion with the exploits of the double-bogie engine, is of not a little interest—we refer to the question of gauge. It is essential to cheapness that the gauge of small lines should be diminished? If this question should be answered in the affirmative, it still remains doubtful whether the advantage of saving thus effected is sufficient to counterbalance the inconvenience of isolating this or that branch from the general railway system of the country, established on the universal gauge of 4 ft. 8½in. But we may state that, since a gauge of 4ft. 8½in. has been found sufficient for the heaviest requirements of our heaviest lines, such as the North-Western Railway, it seems very absurd to widen the gauge, a widened gauge implying heavier rolling stock, for thinly populated districts where the traffic is not to be compared with that of our Midland Counties. In Ireland the engineers ("exuberantly," as Mr. Haughton would say) widened the gauge to 5ft. 3in. In some of our colonies they are still more exuberant, and, for the dear delights of additional expense, lay down a gauge of 5ft. 6in. It is a mistake, for in fact great breadth of gauge is one of those causes which must tend to increase the load of a light goods train. Mr. Bidder has stated that "not a single goods train is loaded up to one-fourth of its capacity"—in which phrase we are to understand goods as not including coals and other minerals. And the reason why goods are thus distributed in trains that might contain four times the quantity will be evident on a little consideration. You can fill a passenger train and empty it quickly, for it empties itself. But goods, which have to be distributed at a number of points in a given line, cannot

be thus quickly deposited from the train as it stops at the different stations. The train cannot wait, and it is found easier in practice to allot a whole waggon, or as many waggons as may be required, to the goods intended for a particular station, and to let the train pass on, dropping whole waggons in its transit. But this implies that goods must be distributed in many more waggons than are necessary for the whole lot, and hence the statement of Mr. Bidder that not a single goods train is loaded up to one-forth of its capacity. Follow this out and see what it means. It means that the goods are put into waggons which are much heavier than is necessary for them. Increase the size of the gauge and you must still more increase the weight of the waggons adapted to it. Diminish the size of the gauge and you can diminish the size of the waggons, diminishing, therefore, the disproportion between the goods to be carried and the capacity of the train to carry them.

What can be done on a railway of extremely narrow gauge is worth noting. The little Welsh railway which we have already spoken of—that from Festiniog to Portmadoc—has a gauge of no more than two feet. It has curves which have been described as being as sharp as the sweep of Oxford Circus; it has gradients of 1 in 80: it has tunnels, one of 60 yards and another of 730 in length; and the inclimation of the whole line with its curves is such that in one direction the train goes down the steep by mere force of gravity. Such is the railway which has paid its proprietors at the rate of 30*l.* per cent. on the original capital, or 12½ per cent. on the total sum invested in it. Now, originally, this railway was worked by horses. Engineers and locomotive builders were afraid of the steam engine as applied to so narrow a gauge, on so steep an incline, varied by such rapid curves. Ten years ago the

foremost engineers declared on Parliamentary committees that locomotive power could not safely or usefully be applied to such a line. And when at length the engineer of the line, Mr. Spooner, determined to test this opinion and to try the effect of a locomotive upon, it he could find no locomotive builder but one who would guarantee the satisfactory performance of locomotives upon the line. That one was Mr. George England, of the Hatcham Ironworks. His locomotives began to work on the Festiniog line in 1863. They did so with perfect success and without accident of any kind ; but in course of time it came to pass that the requirements of the traffic called for still stronger engines, and then it became necessary to resort to Mr. Fairlie's system of the double bogie. Accordingly, two very powerful locomotives of his construction, one called the Little Giant, the other the Little Wonder, have been placed on the line, and by their extraordinary performance add to the wonders of what is itself the most wonderful railway in the kingdom. These results are notable, not as meaning that railways of too-foot gauge are the sort of railways which it should be our aim to construct, but as showing that even on such a gauge, with all its disadvantages of curvature aud gradient—disadvantages which the leading engineers ten years ago declared to be insuperable—the double bogie engine has been found to triumph. In view of such an achievement, we think we have made out a case for inquiry, and may say that if Bogie is a name of terror in legendary lore it ought to be a name of good cheer in railway annals. All hail to Bogie.

THE RAILWAY PROBLEM.

NOTICE No. 3.—*Times of 21st October*, 1869.

We commend the papers we have been publishing on "the Railway Problem" to the attention of all who desire to reconcile the public cry for increased railway accommodation with the shareholders' cry for increased divi- dends. The public demands reduced fares. It calls on Directors to let millionaries or Sybarites go to Inverness for a shilling first-class, and to let the Stoics who cherish a positive hatred of spring cushions go far sixpence. It wants more trains a day, more branch lines. It will put up with no jolting round curves, no collisions, no stoppages in dark tunnels. On the other hand come the shareholders with their claim to larger dividends, and murmurs against the number of half-empty trains and insolvent parasite branches. The public craves for more for its money than it gets at present, and the Companies retort that it gets even now more than it pays for. The existing stato of things being granted to be the only possible state of things, the Companies are right in asscrting the public to be unreasonable. Investors in Railway Stock receive rather less than more than the fair return for their investments. There is no margin of profits out of which additional public accomodation can be carved. But a doubt has for some time been maturing whether the same profits might not be made at a less outlay, and the public take the benefit of the difference. Orthodox railway engineers stoutly affirm the negative. Fares cannot under present circumstances be diminished, because it costs so much

to carry the traffic along the road. It costs so much because so much fuel is required to set the engine in motion, because the line is occupied by any given train for so long a time, and because the rails are worn out in so short a time by a given number of trains. Engineering improvements have had no tendency to curtail this rate of expenditure, but rather the reverse. Lines are obliged to carry more traffic, and at a higher average speed ; but they do it at a proportionate, or more than proportionate, cost in the wear and tear of material. When a line is required to accommodate an increased amount of traffic the ordinary expedient has been, and is, for the engine-builder to augment the motive power, and thereby the bulk and weight of his locomotives, and for the engineer of the Railway to augment the resisting power of his permanent way. The competition has been happily compared to the contest between cannon and armour-plates ; but, as in that contest, so in this, whatever stéel rails a Company can lay down its engine-builder succeeds in battering to pieces.

If this must be so, there is an end to the hope of any substantial reduction of fares—apart, of course, from such as may be made possible by less ambition and litigiousness on the part of Directors. The travelling community ought to "rest and be thankful" that it journeys so cheaply. But certain particulars in the outlay at present needed to provide for railway traffic are so startling that it calls for considerable credulity to believe reform impracticable. In the first place, it is proved on indubitable testimony that, even in goods trains, of the total load dragged along, the goods themselves are only 30 per cent., the remaining 70 per cent. of the weight being dead weight. But in passenger trains, for every passenger that the engine has to draw it has to draw a weight of two tons or two tons and a quarter. That is to say, in

passenger trains only 5 per cent. of the load, according to the most favourable computation, pays. The remaining 95 per cent. travels free, being the wood and iron work of the carriage in which the fare sits. In an omnibus, on the contrary, the non-paying load, the vehicle and horses, weighs only as much as the paying load, the passengers. Under existing conditions, it is, perhaps, necessary that there should be this disproportion on Railways between the paying and non-paying loads. With the velocity of steam, carriages, weighing no more than their occupants would be impossible things to travel in. But it does not follow that the conditions which necessitate all this dead weight cannot themselves be changed. Any such change must produce an equivalent economy in the conveyance, and an opportunity for reducing the fare of the passenger, who now has to frank that huge proportion of dead weight. Every additional ton to be drawn by the engine requires so much additional motive power and fuel. It requires to have either so many additional engines put in motion, or engines of so much additional bulk and power of consuming fuel. But, in fact, the latter is the only possible remedy for the relief of a line from the goods traffic, which is always accumulating and threatening to block it. More goods trains are of no use where every mile of road is already parcelled out for every five minutes of the day among so many passenger trains. Heavier trains, with more powerful locomotives, are the sole specific to save goods trains from stagnating and congealing in unexpected quarters, and becoming anvils for a mail express to beat out the lives of excursionists upon. More powerful engines, however, as at present constructed, devour more rapidly rails as well as fuel. The engineer of a Railway Company's permanent way looks upon them as his natural enemies. He speaks of these Cyclopean monsters as if they took a positive delight in stumbling over

his finest steel rails in order the quicker to hammer them out and crush them to pieces. This ruinous waste, too, like that involved in ponderous carriages, is, under existing conditions, a necessity. The force of locomotives has to be enlarged because the exigencies of a line compel the clearing off of as great a weight of goods as possible in a single train But the more powerful an engine, according to the present principals of construction, the more will it "tremble" or "flounder," and the more, as it rocks from side to side, "bending the rail into a crook "like a dog's tail," will it crush and grind it. But, as we said about the proportion of non-paying to paying weight, so we must repeat about this terrible source of loss to a Company from the ferocity of its locomotives. The damage from their oscillation is on some lines enough to necessitate a renewal of the rails every six months. They themselves suffer correspondingly. So long as this wear of material goes on the profit of the traffic is reduced to a *minimum*. But it does not follow that the oscillation which is its condition and apparent cause should not be itself reduced.

Thus, two main conditions of the smallness of railway profits are the excessive disproportion of the part of the load which pays for being carried to the part which is carried without paying, and the wear and tear of rails and engines. Only 5 per cent. of the weight in passenger trains and 30 per cent. in goods trains pays, and the blows from the oscillation of an engine going at 30 miles an hour are computed to be "60 per cent. added to the weight "upon the wheels." Whatever enables the same weight of passengers and goods to be conveyed at a less expenditure of locomotive force economizes in the same proportion fuel, rails, and engines. Mr, FAIRLIE's "bogie" carriages and locomotives appear to accomplish this end. A carriage under the present

system, in consequence of its rigid wheel base, cannot exceed a certain length, and must be heavy in order to resist concussion. On account of this rigidity in the wheel base of the several carriages the train has a difficulty in passing round sharp curves, which must be therefore avoided by means of expensive cuttings, tunnels, or viaducts. Mr. FAIRLIE, instead of a carriage supported on one rigid wheel base, and therefore limited in length and flexibility, constructs a combined carriage and engine 43 feet long, in its compartments and cognate arrangements like an ordinary train, but which rests on two four-wheel "bogies," one at either end. These "bogies" are small trucks, each of which, unlike the present railway rigid wheel base, works independently, like the front wheels of an ordinary four-wheeled carriage. Consequently the engineer has not to consider the exigencies of the carriage above, but only of the trucks beneath. The carriage, measuring nearly the length of an entire train under the present system, has the same power of passing round the sharpest curves which a carriage a fifth part of the length would possess. The same principle applied to the engine, which in Mr. FAIRLIE's working 43-feet model shares one of the two "bogies" with the end of the carriage, makes it possible to construct locomotives adopted for the bulkiest goods traffic without increasing the weight. The difficulty of increasing power without increasing the pressure—which is what, falling on a single point, destroys rails—is met by lengthening the locomotive, and this is made possible by means of "bogie" wheels, which distribute the weight equally throughout the whole mass.

Mr. FAIRLIE claims for his application of this "bogie" principle to ordinary passenger and goods trains that a ton of passengers will by it make no more than four tons of train load, and that there will be an equivalent gain in the goods

traffic. He claims also that it will render it possible to carry in one train a far greater weight than at present, and at a far less injury from friction to the rolling stock and the permanent way. He claims, even, that it will open the way to dispensing with the costly engineering processes of providing an absolutely smooth, level, and straight course for trains, since his trains, as supple and flexible as each separate wheel system underneath them, and yet as steady and uniform in motion as one solid mass, will be able to double the most abrupt curves and surmount the steepest gradients. If this be not enough, let us add that by one train being enabled to do the work of two the road is to be cleared, the risk of accident diminished, and the cost as well of compensation for life and limb as of a third line of rails to be saved the Company. If the application accomplish on ordinary Railways—and there seems no reason why it should not—what it is reported to perform in Mr. FAIRLIE's cabbage-garden, good days are coming for railway shareholders and passengers alike. Even branch lines may become a profitable investment at last. It has been calculated that one penny a mile saved on all the miles of train run in the United Kingdom in the course of a year would give an additional 618,000*l.* to distribute among the ordinary shareholders, Mr. FAIRLIE's system, on a computation far more modest than Mr. FAIRLIE's own, ought to produce a saving of 1s. 6d. a mile. We are afraid to excite unduly shareholders' hopes by reckoning for them what such a saving means.

CHAPTER II.

THE RALWAYS OF THE FUTURE.

NOTICE No. 1.

THE TIMES, FEBRUARY 18, 1870.

Many persons in England are apt to suppose that we have come to the end of railway extension. The country is so well furnished with railways, and their financial results are so disappointing, that people are naturally loth to cotemplate any further experiments on the established system. We are most grateful to the shareholders who have been so good as to supply us with these admirable roads, which have gone far to change the character of our civilization; but there are not many of us who care to follow their example, and we cannot be surprised if they should themselves be unwilling to continue the sacrifice of their fortunes for our benefit. Still those who are acquainted with the demand for railways in foreign lands, in our colonies, and even in many parts of our own country, must be aware that we are speaking literally when we say that railways are as yet but in their infancy. There is an enormous demand for them in India, for instance; and yet every man of common sense must admit that, judging by all English examples, it is perfect madness to construct them on the received system, which means ruinous expenditure and dead loss. So thoroughly is the need of a great revolution in railway construction perceived that some months ago we had to make the startling announcement that the Governor-

General of India, dissatisfied with the slow progress and excessive cost of railways in his dominion, had actually sent to the United States for engineers who might confer with him as to the introduction of a more effectual and economical system—as if this were beyond the capacity of Engilish engineers; and we propose now to give some account of further most important investigations tending to the same result as that so earnestly desired by Lord Mayo, whose conclusions, it may be mentioned in passing, coincided substantially with those formed independently by the Duke of Argyll at home.

It may be well to begin by reminding our renders that in October last (the 19th and 20th) we gave a pretty full account of what is known as the Fairlie system of railway working—a system by which lines of the lightest construction and very narrow gauge may accomplish work hitherto deemed within the means only of lines of ponderous construction and broad guage, and by which also the established lines of standard gauge may either partly diminish expenses, or, without additional cost, well nigh double their carrying capacity. The characteristics of the system will appear in the sequel; for the present we proceed to state that Mr. Power, the vice-chairman of the Poti and Tiflis Railway Company (a railway of 300 versts in the Caucasus), and Mr. Crawley, the contractor for its construction, were so struck with the merits of the Fairlie system, that they strongly recommended its adoption to the Russian Government, not only for the line prepared in the Caucasus, but also for all lines throughout that vast empire, where railways are of prime necessity, and where now, according to the new plan, five miles can be provided at a cost which was swallowed up in three miles, according to the old one. The recommendation carried the greater weight, inasmuch as the works of the Poti and Tiflis Railway were

far advanced, and on a length of 15 versts the rails are actually laid down. The proposition, therefore, was that the Russian Government would find their advantage, even on these conditions, of changing the plans on which so much work had been expended, taking up the rails which have been laid down, and constructing the line on a gauge of 2ft. 6in., or exactly half the standard Russian gauge. The Minister for Public Works, Count Bobrinskoy, seized upon the idea. Mr. Fairlie went to St. Petersburg to explain his scheme in detail; and the result of all is that an Imperial Commission has been sent over to this country to inspect the actual working of the system in various places, but chiefly on a wonderful little railway of two-foot gauge in Wales.

The Chief of the Commission is Count Alexis Bobrinskoy, cousin to the Minister of Public Works. He is accompanied by a considerable staff of engineers, foremost among whom may be mentioned Professor Saloff, of the Russian Imperial Institute; and Mr. Roehrberg, the manager of the most successful railway in Russia; and by personal friends, as Count Zamoyski and Count Alexander Berg, who take an interest in the question of railways. At the same time Mr. Fairlie offered to the Indian Government the opportunity of witnessing the experiments to be instituted for the Russian Commissioners; and they, being themselves anxious for the means of improving and economizing their own railway system, at once resolved to take advantage of the offer. They appointed a Commission, consisting of Lieutenant-General. Sir William Baker, R. E., and a member of the Council of India; Mr. Thornton, Secretary of the Public Works Department in the India-office; and Mr. Danvers, Government Director of Indian Railway Companies, to accompany the party. Captain Tyler also, the Government Inspector of Railways,

who has already reported favourably on the Festiniog Railway of two-foot gauge, attended on behalf of the Board of Trade, and Mr. Pihl, Chief Engineer of Railways in Norway, was present on the part of the Norwegian Government. Besides these gentlemen, who went to witness the trials officially, others took an interest in the various proceedings in a private capacity; chief among them being the Duke of Sutherland and Count Béla Széchenyi, son of the Hungarian patriot of that name, who was well known in England some 30 years ago. The Duke took an especial interest in the inquiry, as he is not only a director of the North-Western Railway Company, but is himself the proprietor of a considerable length of railway on his Sutherlandshire estates.

The party thus constituted started off on Thursday morning last in a special train of saloon carriages, and halting at Crewe to view the magnificent works of the North-Western Railway—the largest in Europe, with the exception of those at Creuzot, in France—proceeded by Shrewsbury into Wales. At Welshpool they entered upon the Cambrian Railway system, and, with the advantage of brilliant weather, were conducted by Mr. Elias through the very picturesque country, up hill and down dale and round curves of hill sides, by which the line passes to Portmadoc. At Portmadoc is the terminus of the line known as the Festiniog Railway, of two-foot gauge (really one foot 11½ inches), which was the principal subject of investigation.

The Festiniog Railway, which is pronounced by no less an authority than Captain Tyler, the Inspector of Railways, to be the most instructive line in the three kingdoms, and which seems destined by its success to give a new impulse to railway engineering, is itself one of the oldest in existence.

The Act for it was obtained in 1832, but in the first instance it was constructed only for horse traction. It is a single line, 13¼ miles in length, with a branch of one mile connecting the slate quarries of Festiniog with the quays of Portmadoc. The terminus at Festiniog has 700 feet of elevation above that at Portmadoc, the average gradient being one in 92, which is enough to secure the descent of the trains on the return journey from Festiniog to Portmadoc by the impetus of gravitation—or, as the Welshman puts it, "by its own impittence." The line runs through a rude, rocky country, and has to adapt itself to an endless variety of curves along the contour of the hills, so that a train of any length has frequently to wriggle in serpentine fashion along two or three reverse curves, some of them sharp enough—the radius being 1¾ chains. On these curves the cant or super-elevation of the outer rails is never more than three inches. The line, in the old days when it was worked by horses, was originally laid with rails of 16lb. to the yard. When, about eight years ago, it was adpated to the locomotive, it was fitted with rails of 30lb. to the yard, most of which have been in use ever since. These, however, were found too light for the work, and are now being replaced by double-headed rails of 48½lb. to the yard. The wheels of the carriages being less than 2 feet apart, it is found convenient to arrange most of those for passengers after the fashion of an Irish car, with footboard overhanging the wheels. In this way the carriages are so low hung, and even carriages of the ordinary build are so near the ground in consequent of the small diameter of the wheels, that the expense of platforms at the stations is avoided. The whole expense of constructing and reconstructing the line, including tunnels, one of them 700 yards in length, with branch lines to the slate companies inclined planes and the quays at Portmadoc—in all 14 miles, has been 75,000*l.*, or at the rate of 5,378*l.* a mile,

The value of the rolling stock on the line is 28,000*l*, or at the rate of 2,000*l*. a mile. And now comes the most important point of all, which is that the original capital of the company is 36,185*l*., and that all the extra money which has been laid out upon the line has been taken from revenue. In this sense, therefore, as the net revenue of the company is 10,622*l*., it appears that the line yields a dividend of 29½ per cent. on the original capital. A sum of 50,000*l*., however, paid out of revenue for improvements and reconstructions, has been capitalized—making the total capital 86,185*l*. In this sence the net revenue of the line yields a dividend of 12½ per cent. Whichever way the fact is to be stated, it is a most remarkable one, and must fill many a share-holder's heart with envy.

The chief cause of this wonderful result is the narrowness of the gauge, which has enabled the Festiniog Company to economize in many ways. Thus, for example, the trucks for goods or minerals, even when fully loaded, have less of dead weight on a narrow than on a broad gauge. The best waggons on the standard gauge of 4ft. 8½in. are reckoned to weigh about 7cwt., and to carry 12½ cwt. of pig iron or coal for every foot of their length, the dead weight being in the proportion of 56 to 100 of the *maximum* paying load, or 36 per cent. of the entire load. On the other hand, the waggon for a three-feet gauge is calculated to weigh 2½cwt, and to carry 8cwt. for every foot of its length, the dead weight in this case being a very little over the proportion of 31 to 100 of the *maximum* paying load, and under 24 per cent. of the entire load. But there is still another point of view from which it can be shown that the waggons for goods and minerals on a line of narrow gauge are not so disproportianate in weight to the weight carried as they are on the braod gauge. In goods traffic it is well known that the dead weight of train

is enormous—something like 70 or 80 per cent. of the total weight hauled. If goods are to be delivered on a long line of railway, they are in this country arranged in many more waggons than are necessary to hold them, because a goods waggon cannot, like a passenger carriage, unload itself, and the train cannot wait till the unloading at a particular station is finished. It has to pass on, leaving the waggon of goods for that station behind; and it is more than probable that for this purpose the waggon has been but half or a quarter loaded. This becomes serious when waggons that weigh several tons carry but a fraction, often a small fraction, of their own weight. Such a source of expense disappears to a large extent on a narrow-gauge line, where the waggons are comparatively small, and it is but one example of the saving which may be effected in the working of such a line in addition to the saving of cost of construction in the first instance.

This remark would hold good of the narrow gauge in itself and worked according to the ordinary system; but it is in the working of the Fairlie system that the greatest saving of all is effected, and it is mainly, indeed almost entirely, in consideration of the economy, the increased power, and the diminished wear and tear which this system implies that a much narrower gauge than that now in general use has begun to find favour in the eyes of practical men. It was long before the Festiniog Railway Company could get an engineering firm to undertake to build a locomotive for a line of such steep gradients, combined with sharp curves, which they could guarantee. At last Messrs. George England and Co. undertook the task, and supplied engines which worked with perfect success, and then people began to believe in a railway of narrow gauge. One of Mr. Fairlie's engines has now been built for the line—it is called th Little Wonder, as the other

engines which have preceded it have been called the Welsh Pony, the Little Giant, as well as by other diminutive names —and the result has so surpassod expectation in the power it exerts, in its gentleness of action, in its economy of fuel, in its saving of the rails, and in its adaptation to troublesome curves and gradients, that for the first time practical men have discovered that a gauge of 2ft. 6in., or 3ft. at the very utmost, is enough for the heaviest traffic. It is no secret that two engineers of eminence, Mr. Fowler and Mr. Fairlie, have pronounced a 3ft. gauge to be ample for all the requirements of India, and there were men of position in the party which went down to Wales, men with characters to lose, who made what seems to us the hazardous statement that on a gauge of even 2ft. 6in. they would undertake, with the Fairlie engine, to work the heaviest traffic in the world—that of the London and North-Western Railway. Be that as it may, it must be strange for those who can remember the battle of the gauges to find that what was then known as the narrow gauge is now in its turn attacked as being much too broad, and is even described in the terms which have been applied to more than one scheme of the Brunels as a gigantic folly. Our 4ft. 8½in. gauge is now established in so many countries—it is used not only in Great Britain, but also in France, Belgium, Switzerland, Italy, Austria, Prussia, Denmark, Egypt, the Cape of Good Hope, Australia, the United States, and Central America—that we seem to think of it as a standard of perfection. In some countries there will be found a still broader gauge—as in England itself, in Ireland, in the United States, in Canada, in Australia, in India, in South America, in Portugal in Spain, in Russia; but in very few will a narrower gauge be found. In England we have 14 miles on a 2ft. gauge, and a few more on a sligthly broader guage; in Belgium there is a 3ft. 8in. gauge; in France, a 3ft. 4in. gauge; in India may

be found a 4ft. gauge; and in Norway and Sweden one of 3ft. 6in.; on the Mont Cenis Railway there is a 3ft. 7½in. gauge; and in Queensland one of 3ft. 6in.; and now we have opinion tending towards a gauge of 2ft. 6in., or of 3ft., as the standard for the future.

It is easy to determine on light railways of narrow gauge, and to construct them. The difficulty is to work them, and to work them in such a manner that their capacity and their economy shall bear comparison with railways of larger design and more elaborate construction. Hitherto railways of light canstruction and narrow gauge—that is, narrower that 4ft. 8½in.—have been in little favour, because of the limited power and destructive effects of the locomotive. Take for example, the oscillation. This is very destrictive on the standard gauge; it is, indeed, the chief cause of destruction to the permanent way—a fearful item of expense. But it is still worse on a narrow gauge, and necessitates diminished speed on battered rails. Therefore, practically, a narrow gauge was but of limited application to ordinary traffic until a locomotive, such as that of Mr. Fairlie, could be invented, free, or nearly free, from oscillation. And again, since a narrow gauge generally implies lightness of construction, and since lightness of construction implies sometimes roughness of workmanship, and nearly always such an adaptation of the railway to the surface of the country that it must dispense to a great extent with cuttings, viaducts, and other works, and must be ready to accept to the fullest extent possible a line of sharp curves and heavy gradients, it was necessary to devise a locomotive for it capable of good and safe speed on these conditions; and there was none such of sufficient note in existence until the double bogie engine of Mr. Fairlie was produced, which combined great size and power with freedom

from oscillation and with a short wheel base that could be worked round curves of 60ft. radious and even less.

We must reserve for a day or two a full description of the performances of Mr. Fairlie's engines in Wales, because it is desirable to give the results of all the experiments, with their success and their failure, together. The last of the experiments is made to-day, and we shall state all when we know all; but in the meantine we cannot be wrong in saying that there was an absolute unanimity of opinion among all those who witnessed the working of that narrow gauge railway at Festiniog that the standard gauge of 4ft. 8½in. is far beyond all ordinary requirements. There may be some difference of opinion as to the precise gauge which is best. Mr. Spooner, the engineer of the Festiniog Railway, strongly advocated a gauge of 2ft. 6in., and he was supported in this view by practical men of great experience; others seemed to hold that a gauge of 3ft., giving greater freedom of space, would be best, but all appeared to be convinced that a gauge much narrower than that now in general use is capable of work which is at present little imagined in the railway world. If this view be correct, it involves some most important results. Thus, let us take an ordinary line costing 15,000*l.* a mile, and compare it with one of narrow gauge worked in the new system, with power of carrying equal paying loads, and costing, as we have already indicated, three-fifths of the price of the other—namely, 9,000*l.* With a traffic return of 20*l.* every week for every mile, and deducting 50 per cent. for working expenses, the one railway would yield a dividend of about 3½ per cent., while the other would yield very nearly 6 per cent.; and this calculation makes no allowance for the more economical working of the narrow gauge, which is one of the main features of the system. If such a result be possible it implies

for public lines not a little encouragement to carry the railway system into every nook and corner of the kingdom where a moderate traffic may be obtained; and for Government lines the reduction of tariff to the lowest point.

There seemed to be a unanimity of opinion also as to the success of Mr. Fairlie's engine adapted to the narrow gauge, and also on the broad gauge; but it remains to be seen, from the reports which will be furnished to the various Governments, how far this unanimity extends. That the engine did some extraordinary work is clear, as we shall have to show in a future article; but whether it is or is not to be recommended for adoption as a means of making the narrow gauge available to the utmost is a point on which we have no information.

THE RAILWAYS OF THE FUTURE.

NOTICE No. 2.—*Times of 1st March*, 1870.

The object of the experiments on the Welsh railways was to ascertain whether or not the Fairlie engine increased the carrying capacity of a railway or diminished the cost of working it. With this view two engines were put on their trial—one, the Little Wonder, on the Festiniog Railway, of 2ft. gauge, in North Wales; the other, the Progress, on the ordinary gauge of 4·8½, in South Wales.

The Fairlie engine consists of one long boiler, having two sets of tubes, with double firebox between, and poised on two bogies. The arrangement is such that an enormously increased power is gained, with an extraordinary facility of movement upon swift curves, and with a freedom from oscillation which makes the Fairlie engine less destructive to the rails than locamotives of much less weight and power. The value of the system depends chiefly on the two bogies. It may be necessary to explain for some readers that a bogie is simply the name for a small truck. Instead of resting a waggon or a locomotive upon wheels of its own, which would make a long wheel-base that could not by any possibility get round very sharp curves, and that might get round moderate curves, but only with an amount of flange-friction destructive to the rails and retarding speed, the waggon or locomotive is poised on two independent trucks, which have a short wheel-base, and which can, therefore, find little difficulty

in curves of exceeding sharpness. In the small cabbage-garden at Hatcham, half an acre in extent, and laid out with rails of the ordinary gauge, Mr. Fairlie exhibits a steam carriage of 43ft. in length travelling at a speed of 25 miles an hour round curves of 50ft. radius; and they could with equal ease, and even greater safety, travel round curves of 25ft. radious, which is only about that of an ordinary engine turntable. The engine, therefore, on a pair of bogies is prepared for a circuitious line of country, even on the standard gauge, which engines of the current type could not attempt.

The excellence of the bogie, however, does not merely consist in its adaptation to curves. It has an extraordinary effect in reducing oscillation. An ordinary carriage rests directly upon the ends of axles, and when, through any defect in the road, there comes a disturbance in the plane of movement, the carriage, waggon, or locomotive rocks from side to side with immence violence in a series of oscillations that hammer the rails to their destruction. It is calculated that these oscillations in a train going at the rate of 30 miles an hour add more than half as much again to the normal weight upon the wheel; and this is very serious in the wheels of a locomotive, each of which may be loaded up to seven or eignt tons. The oscillation is reduced to a *minimum* by means of the bogie, inasmuch as the vast superincumbent weight of of the locomotive is balanced on a pin, called the bogie-pin, in its centre. The bogie is a flat table upon wheels, with a great pivot in the middle of it. This table, and the wheels which support it, must naturally submit to whatever deflections there may be in the road, and so far it is impossible to get rid entirely of oscillation; but the great mass of weight above, being poised in the centre of the bogie, and upon the centre of the roadway, is comparatively free from the

influence of rocking, and transmits little or no hammering to the rails. A child can understand this by watching at see-saw the difference between placing a weight in the middle of the plank and dividing it between the ends. Now it is an enormous advantage thus to steady the locomotive, to reduce the tendency to oscilliate, and to get rid of the violent impact upon the rails. To steady the locomotive is to make its motion safer, and to diminish the chances of its leaving the rails—a point of considerable importance on the narrow gauge. The most important point of all, however, is to save the rails, which are so perishable under the demands of a heavy traffic that there are instances in which the strongest steel rails have to be replaced in six months. The rails where the line has any curve are torn up by the flange-friction of monster engines with an immense wheel-base, and, whether the line is curved or straight, are hammered out by the oscillations of the same engines. We have already explained how, in the Fairlie engine, the flange-friction is reduced by the substitution of bogies with a short wheel-base for the old plan which necessitates a long one; and there is an absolute unanimity of opinion as to the disappearance of oscillation with the use of the double bogie.

We have only one word more of preface before we proceed to state what were the experiments with the Fairlie engine, both on the narrow and on the broad gauge. It is that the statements we are about to make do not rest solely on our authority. The various Commissioners and other observers met together under the presidency of the Duke of Sutherland, compared their notes point by point, and came to a perfect agreement as to the facts which they were prepared to vouch for. Our facts, therefore, have the authority of documents signed by the Duke of Sutherland, as chairman of the

different meetings which were held; by the Russian Imperial Commissioners; by the Commissioners of our Indian Government; by Captain Tyler, of the Board of Trade, who acted as Secretary, and was mainly instrumental in putting the facts into proper form; and by others who were well able to judge.

The Little Wonder is an eight-wheeled double-bogie engine of four cylinders 8 3-16in. in diameter, with a stroke of 13in. The diameter of its wheels is 2ft. 4in.; its average steam pressure is 150lb.; its weight is 19½ tons; its total length is 27ft.; its total wheel-base is 19ft., and the wheel-base of each bogie, which practically has alone to be considered, is 5ft. This engine was first of all made to carry from Portmadoc to Festiniog a train made up of 90 slate-waggons, weighing 57½ tons; 7 passenger carriages and vans, weighing 13½ tons; and 57 passengers, weighing 4 tons—in all, 75 tons. Add to this its own weight, and we have a total load of 94½ tons. The weight, it will be seen, was considerable, if we take into account the size of the engine, the narrowness of the gauge, the steepness of the gradients, and the sharpness and multitude of the curves. But the chief point of interest in this experiment had reference to the length of the train, which was 854ft.—nearly the sixth part of a mile. A train of such a length on such a line had to run often upon two or three reverse curves, some of them with a radius as short as 1¾ chains, and it curled and doubled upon itself as it wound among the Welsh hills to that the passengers in the front carriages could sitting in their seats, make signals to the passengers in the hindmost ones. The engine, being in full gear, took this very long train up the hills and in and out among the curves at an average speed of 14½ miles an hour, and at a *maximum* speed of 26½ miles. Let us here add by way of parenthesis, in order not to refer to it again, that some days afterwards a similar train of 140 empty and seven loaded

waggons, weighing in all 101 tons, and measuring in length 1,323ft.—*that is, a quarter of a mile*—a train so long, in fact, that there were parts of the road on which it had to run on no less than five reverse curves—was by the same engine hauled up the hills at an average speed of 12½ miles, and a *maximum* of 16½. Now, what was the result observed in wriggling along these curves? It was generally observed (we now quote almost *verbatim* from the protocol signed by the chief witnesses) that even on curves of 1¾ chains radius, and at *maximum* speed, there was very little perceptible oscillation or movement on the engine or in the carriages, and by no means such as is felt on comparatively easy curves on ordinary railways. Nor must this remarkable point be forgotten—a fact almost incredible, but yet certified by competent witnesses—*that the oscellation diminished as the speed increased.* The speed, let it be added, is naturally less on a narrow gauge than on a broad one. Captain Tyler, the Government Inspector of Railways, was at first so doubtful of the safety of a high speed on a railway of such narrow gauge and such wild curves as that at Festiniog that he insisted on limiting the company to a *maximum* speed of 12 miles an hour. Since then, however, his doubts have been so completely dispersed that he has removed all restriction as to the rate of speed; and as a matter of fact the Little Wonder, when necessary, works up to 30 and 35 miles an hour.

Next day the oscillation of the Little Wonder was put to a further test, and compared with that of the other engines —the Welsh Pony and the Mountaineer—which are of the ordinary type. In this series of experiments the speed was confined to ten or 12 miles an hour on a comparatively level line, the gradient being only 1 in 1,200; and the line was laid with rails weighing only 30lb. to the yard, and not fished

at the joints. On the Welsh Pony and the Mountaineer, tank engines of the ordinary type, weighing, the one ten and the other eight tons, it was found that there was a strong vertical oscillation and a lateral oscillation not so strong. On the Little Wonder, the double-bogie engine weighing 19½ tons, it was found that when riding on the foot plates there was no oscillation whatever, vertical and or lateral, perceptible—only "a smooth, floating movement;" and that when riding on the bogie frames there was felt a slight lateral oscillation, though less than on the other engines. It is added that the oscellation of the Fairlie engine being confined to the bogie, the influence of the impact on the rails from the flanges of the wheels was far less than in the case of the Welsh Pony and the Mountaineer, the whole weight of these engines being in the course of their oscillations brought to bear upon the rails.

Next followed some rather tedious but very interesting trials as to the comparative powers of the two classes of engine. The Welsh Pony was selected to represent the common type of engine. It is a four wheeled locomotive, weighing 10 tons, with cylinders 8⅛in. diamer, having a stroke of 12in., and with wheels 2ft. in diameter. It was in the first instance tacked on to a load of 50 slate waggons full of slate, weighing 123½ tons. To this add 3½ tons for passengers and 10 tons for its own weight, and we get at the entire load of 137 tons. With this the Welsh Pony started from Portmadoc, and, running along the comparative level (1 in 1,200) of the Traeth Mawr Embankment, stopped on a gradient of 1 in 85, unable to proceed further, with 160lb. to the square inch of steam pressure. Hereupon half the number of waggons was removed, and the load (including passengers and the engine itself) was consequently reduced to 72 tons 17cwt. With this load

it was found that the Welsh Pony could mount the gradient of 1 in 85 easily enough. Being successful with 25 waggons, the question arose could it manage more? It was then tried with 30 waggons, but on the gradient of 1 in 85 it was found that it could not start, though, since the engine-wheels did not revolve, there was no lack of adhesion. Then again the load was reduced to 26 waggons, weighing (with passengers and engine) 73 tons 16 cwt., and it was found that this was the limit of the Welsh Pony's power. It started with such a load on the gradient of 1 in 85, and carried it as far as was necessary at the rate of five miles an hour—the average pressure being 150lb. to the sqnare inch. If the Welsh Pony could carry nearly 74 tons up such a gradient, and with this load also start on it, what could the Fairlie engine, the Little Wonder, do? It was supposed that it ought to pull double. If the Welsh Pony could, on a gradient of 1 in 85, manage 26 waggons full of slate, weighing with all else 74 tons, surely the Little Wonder could manage 52. Mr. Fairlie said he was quite prepared for this; he would stake the credit of his little engine on its power to carry such a load; and to show that he could be generous, he even added three waggons to the load; he thought his engine could manage 55 waggons. However, as the Welsh Pony had first of all been tried with an excessive load, it was but fair that the Little Wonder should be similarly tried. A train was prepared of 72 loaded waggons of slate, weighing 138 tons 17 cwt., with empty ones weighing 43 tons 10 cwt.; and when you add to this 56 passengers, weighing 4 tons, aud the weight of the engine itself, 19½ tons, you have a total load of 206 tons. Wth this load the Little Wonder started from Portmadoc (steam pressure, 165lb.), and passing along the level embankment, went up the gradient of 1 in 85 with perfect ease, and to the astonishment of all the visitors, who crowded round Mr. Fairlie and

shook him heartily by the hand on such a triumph. His engine was warranted to do double the work of ordinary engines, and on trial it was found equal to treble the work. But then arose the question—The Little Wonder has pulled such a load up the gradient of 1 in 85, having had a good start on the level embankment; can it start with this load on the gradient itself? It was, perhaps, scarcely fair to make the trial, inasmuch as the day was wearing late, and the engine-driver had, through a misapprehension, let the fire run low. Still the trial was made, and with perfect success. There is this further, however, to be added, that whereas the shorter trains were standing when they started, or attempted to start, partly on a curve of 4½ chains radius, partly on a straight line, the train of the Little Wonder being much longer (it was 648 feet), stood partly on the curve of 4½ chains radius and partly on a reverse curve of a little wider sweep, which of course, means an increased resistance, and might be resolved into an increase of gradient. Also let us add here, to complete the statement, what really happened four or five days afterwards, that whereas these experiments last described were intended to test the extreme power of the engines, other experiments followed to show what the Little Wonder could do, not merely in a short run, but in its ordinary daily work between Portmadoc and Festiniog. It took, for example, a train 407ft. long, and loaded to 141½ tons, from Portmadoc to Festiniog, at a *maximum* speed of 15 miles an hour and an average one of 11¼. The usual practical load, however, of the Little Wonder upon the average gradient of 1 in 92 is from 90 to 100 tons (exclusive of engine), at from 12 to 15 miles an hour. On a level it is calculated that its power is equal to the carriage of 450 tons, at a speed of 14 miles an hour.

After the experiments on the Festiniog Railway the exploring party met together in council, under the presidency

of the Duke of Sutherland, to hear Mr. Spooner read a paper on the wonderful little line of which he is the engineer, and to compare with each other their notes and impressions. Mr. Spooner gave ample information on every detail connected with his railway, which in the year ending June, 1869, had a mineral traffic of 118,132 tons, a goods traffie of 18,600 tons, and a passenger traffic of 97,000 persons, but no night traffic and no Sunday trains. His paper will, no doubt be published, and those who may be interested in the subject will find in it all the statistics of which we have given the cream. We only state here that he wound up his remarks by saying that he does not recommend for light railways a gauge so narrow as 2ft. The gauge he recommends is one of 2ft. 6in. The large amount of traffic which can be done with ease on lines of this limit is, he said, really surprising, and with the Fairlie engine it is quite equal to that which can be earned on a 4ft. 8½in. gauge. Hereupon the discussion became general, but we can refer to only a few of the opinions which were expressed. The Duke of Sutherland said he wished he had known more of the Festiniog Railway six years ago. "I have expended," said his Grace, "about 200,000*l.* in promoting and making railways in the north. Had these lines been constructed on the narrow gauge, and had they in consequence cost only two-thirds of the sum that has been expended on them, I should have obtained a direct return on this large sum which I have laid out for the benefit of my estates and of the people in those remote districts. As it is, I shall suffer considerable loss. Then Mr. Crawley insisted in a vigorous argument on the perfect sufficiency of a 2ft. 6in. gauge, if worked on the Fairlie system, for the heaviest traffic, and on the folly, if this were sufficient, of adding another inch to the gauge. The argument may be sound as regards heaviness of traffic, but as other considerations besides the weight

to be carried have to be taken into account, as, for example, the comfort of passengers, and the bulk of goods, say in a cotton country, it is natural that there should be some difference of opinion as to the precise narrow gauge which is best. It will be seen that Mr. Fowler and Mr. Fairlie have both recommended a 3ft. gauge for India ; and it is not at all unlikely that this gauge may ultimately be adopted in Russia. It is important that on this subject we should give the views of Captain Tyler, whose scientific attainments, and whose large experience as the Government Inspector of Railways, give a pecular value to his opinions. He stated in substance at the meeting of Commissioners what will be found more elaborated in his printed reports. Thus, in a paper which he read on April 11, 1865, before the Institute of Civil Engineers, he says :—

"It is illegal at present to construct any passenger lines in Great Britain on a narrower gauge than 4ft. 8½in., or in Ireland than 5ft. 3in. The Act 9 and 10 Victoria, cap. 87, provides (section 1), 'that after the passing of this Act it shall not be lawful (except as hereinafter excepted [with reference to broad gauge railways]) to construct any railway for the conveyance of passengers on any gauge other than 4ft. 8½in. in Great Britain and 5ft. 3in. in Ireland ; and (section 6), 'that if any railways used for the conveyance of passengers shall be constructed or altered contrary to the provisions of this Act, the company authorized to construct the railway, or, in the case of any demise or lease of such railway, the company for the time being having the control of the works of such railway, shall forfeit 10*l.* for every mile of such railway which shall be so unlawfully constructed or altered during every day that the same shall continue so unlawfully constructed or altered ;" and section 7 gives power to the Commissioners of Woods, &c., or to the Board of Trade, to abate or remove such railways, so constructed or altered, contrary to the provisions of the Act. It would therefore appear to be necessary, before constructing any railways for passengers on a less gauge than 4ft. 8½in., or before attempting to open for passenger traffic

any railways so constructed subsequently to the year 1846 (in which the above Act was passed), to endeavour to obtain, if not its repeal, at least a modification of its provisions. That Act was passed after the Report of the gauge Commissioners, when there was a strong feeling against break of gauge, and when there was no immediate prospect of a third and narrower gauge being extensively required. But there is now an increasing demand for branch railways of a minor class. Many coal and mineral lines are in use on a narrower gauge than 4ft. 8½in., and others are about to be constructed with ultimate views of passenger traffic. It would therefore be an advantage if some smaller gauge were recognized; for, however objectionable the existence of different gauges on important through lines of communication may be, it is quite otherwise with respect to the use of a narrower gauge for feeding branches, in districts where a similar gauge to those main lines would not be commercially practicable. Passengers change carriages under any system at the junctions of less important branches, and it is considerably cheaper to transfer heavy goods from one railway truck to another, than to cart them for several miles, perhaps over different roads. The Festiniog Railway, on which the original gauge has necessarily been maintained, in consequence not only of its own works, but also of those of the tramways and quarry inclines running into it, is an extreme example, outdone only by the little engine which does the work of the shops at Crewe on a gauge of 18in.; and the cost of that railway, under the peculiar circumstances of its original construction and subsequent alterations, cannot be taken as a guide for the future. A gauge somewhat wider than 2ft. would probably be desirable on any line to be now constructed, and it would hardly be worth while to desert the gauge of 4ft. 8½in. in Great Britain for any gauge wider than 2ft. 6in. But whatever the exact gauge, whether 2ft. 6in. or 3ft., or any other dimension that might be considered most suitable for lines of *minimum* traffic, there can be no question that a system of branch lines, costing two-thirds of the branches now ordinarily constructed, and worked and maintained at three-fourths of the expense of those branches, would be of decided benefit to Great Britain and Ireland, and would be most valuable in India and in the colonies; in fact, wherever there are people to travel, produce to be transported, or resources to be developed, where it would not be commercially profitable to incur the expense, in the first instance, of a first-class railway."

On the same occasion he observed :—

"It is important to ascertain what would be a suitable gauge in those instances where the traffic is not likely to be large. Farmers are now using portable railways for transporting the produce of their fields. For bringing in their harvests, spreading manure, &c., and there seems no reason why districts which could not support a railway on the gauge of 4ft. 8½in. should be altogether deprived of the advantages of railway communication. The question of gauge is in one sense a question of speed. Speaking roughly, on a railway of 2ft. gauge, with 2ft. driving wheels, travelling might be made as safe at 20 miles per hour as on the Great Western, with its 7ft. gauge and 7ft. driving wheels at 70 miles per hour. I have travelled on parts of this little line at the rate of 30 miles per hour with every feeling of safety."

And again in a report on the Festiniog Railway, addressed to the Board of Trade, he says :—

"The adoption of locomotive power upon this little line is very important, and has evidently been a very successful experiment. The cheapness with which such a line can be constructed, the quantity of work that can be economically performed upon it, and the safety with which the trains run over it, render it an example which will, undoubtedly, be followed sooner or later in this country, in India, and in the colonies, where it is desirable to form cheap lines for small traffic, or as a commencement in developing the resources of a new country."

It should be noted particularly that the inquiries instituted by the Russian and Indian Governments had reference not merely to the narrow gauge but chiefly to the narrow gauge as made available by the Fairlie engine. Having examined into the working of the Fairlie engine on the narrow gauge they proceeded southwards to see the working of another engine of the same type on the ordinary gauge, on the heavy gradients of the Mid-Wales Railway and of the Brecon and Merthyr line. The Progress was, we believe, the first built

of Mr. Fairlie's engines, and has several imperfections, being, for instance, deficient in heating surface. But taking it as the first rough exemplar of the system, its performance is certainly remarkable. It is a double engine, with a four-wheeled bogie under each end, the cylinders 15in. in diameter, the stroke 22in., and the wheels (4ft. 6in. in diameter) are coupled together in both bogie frames, so that all the wheels of the engine are driving wheels. The extreme wheel base is 22ft., but, what has alone to be considered in practice, the wheel-base of each bogie is only 5ft. The heating surface is on the fire-box 92ft., and in the tubes 1,901ft., making a total of 1,992ft. The total weight of the engine when fully equipped is 54 tons, including 1¾ tons of coals and 2,000 gallons of water. Also, the engine is fitted with the Chatellier steam break, which Mr. Fairlie was the first to introduce into this country, and its extreme length from buffer to buffer is 32ft.

On the 14th of February the Progress left the Three Cocks Junction on the Mid-Wales Railway with 39 loaded waggons, three break vans, and about 50 passengers and workmen, making a total weight of 526 tons, including the engine. It measured 732ft. in length. The day was bitterly cold; the hour was late; Mr. Fairlie was anxious to hurry on; and not waiting for the engine-driver, who knew the road, he mounted the engine himself, and set off with his load. The result proved that though he may be a first-rate engineer he is not a good engine-driver. A man may be a very good judge of horses and yet not a good jockey. An engine requires as careful management as a horse; and Mr. Fairlie, driving his own engine, made it go through its heaviest work; but when he came towards the end of the journey, and there was a trifle more to be done, it turned out that there was not

THE RAILWAY NEWS.—March 12, 1870.

"THE RAILWAYS OF THE FUTURE."

Uuder the above heading there appeared in the *Times* of February 18 and March 1 two very remarkable articles on this all important question—remarkable because of the intelligible manner in which the subject, in itself a most complicated one even to those learned in the profession of engineering, has been simplified and laid before the world, so that all who read can understand. We are glad to see the leading journal giving so much prominence to a subject which has occupied much of our space. We have deemed it one of the most important questions of the day, and its proper solution would, we are certain, be hailed as the greatest boon to the country at large, and to the great body of shareholders in particular, whose special interests it has always been our aim to protect. We have carefully watched the progress made by Mr. Fairlie with his system, and it is most gratifying to us to find that all we have stated in favour of it has been more than borne out by the results of the experiments which gave rise to the articles in question; the detailed account of these experiments, as made by the Commissioners under the presidency of the Duke of Sutherland, was published in our columns at the time. There were, however, two very material points in the discussion which took place after the reading of Mr. Spooner's paper at Tanybwlch, on the working of this little railway, which the *Times* has omitted to notice, to which we

wish to draw attention. These were, first, the relative dead weights carrying a ton on the broad—*i. e.*, 4ft. 8½in.—gauge as it is, and on the 2ft. gauge—the narrow gauge is now becoming so popular that the hitherto narrow gauge—*i. e.* 4ft. 8½in.—must henceforth be called the broad gauge—and, secondly, the consumption of fuel in the Fairlie as compared with ordinary engines.

We desire to call attention to these because of their importance to the general question, and because they are not properly known. The results now so highly favourable to the narrow gauge and the Fairlie engine might lose much of their value if they are brought at too high a price in dead weight in the former, and too large a consumption of fuel in the latter. It was thought just possible we might be paying too dear for our whistle, and this view of the case evidently occurred to several members of the Russian and Indian commissions, who had so carefully watched every feature of the experiments' in order to satisfy themselves of their genuine character. These questions were very satisfactorily replied to by Mr. Spooner, who stated, roughly speaking, that the proportions were 3½ tons paying weight to 1 ton of dead weight; but in many case it was much more, as he often carried 8 tons of timber in two 12 cwt. trucks. With respect to the consumption of fuel in the Fairlie engine, Mr. Spooner alleged that there was saving of 25 per cent. over the ordinary engines for the same amount of work done. Mr. Crawley, contractor of the Poti and Tiflis and Mexican Railways, asked if Mr. Spooner meant that, taking one of his ordinary engines singly, or coupling two together to do a given duty, that the consumption would be 25 per cent. less with the Fairlie engine doing the same duty. For instance, if the two couple engines used 200bs. of fuel to carry 100 tons a given

distance, would the Fairlie engine do the same work in every respect with 150lb? Mr. Spooner's reply was, "Certainly it would." And he further added that he had carefully investigated the matter during the eight months he had had the Fairlie engine at work.

Now, what we desire to say is this—the results of the experiments made have been truly recorded, independently of their being certified by the Duke of Sutherland and the Commissioners, and it is within our knowledge that they are correct. Then why should there be any more hesitation about adopting a system which has given such results? Why on earth do we go on building expensive broad gauge lines, especially in our colonies and India? Are we to remain tied in the hands of the few obstructives who say we won't move on? Are those portions of our island which have no rail accommodation to remain in that condition because we connot build railways that will pay, and because we may be told, as the Brighton Railway shareholders were, that we had better light our pipes with our bank-notes? We think not; the time has now arrived for ascertaining why this system of double-bogie engines is not adopted.

If, as the *Times* says, they run infinitely smoother than other engines—the Commissioners call it a smooth floating movement—that they do not "murder the rails in their violence," and, as Mr. Spooner says, there is a very large saving in fuel for the work done, with a great economy in wages, why should we lose further time in their introduction? If all that has been stated in favour of this double-bogie engine, or part of all, or any, can be contradicted by those who are opposed to the principle, why don't they come forward and do so?

Mr. Fairlie states very distinctly that he can produce engines that shall weigh no more for wheel than the load now on an ordinary coal truck, but yet capable of hauling as many tons in a train as the most powerful monsters which are now so heavy as to "murder the best steel rails" in a very short time; that these engines will work well on light and cheap lines with 40lb. iron rails, the latter lasting twice as long as the heaviest steel rails on the best-laid lines; that he can make a 2ft. 6in. gauge line, work as many tons over it, and in the same time, as the most capable 4ft. 8½in. gauge line now existing, with an enormous reduction in dead weight; and, finally, that he can, with the assistance of the Ramsbottom water troughs, double the carrying capacity of the very best lines in the country. These are very plain and very distinct statements, which it is so easy to upset, if not true, that we wonder why those who are so opposed to the system do not at once come forward and expose the fallacy, if fallacy it is. Mr. Fairlie is no conjuror; his engines are open to the inspection and criticism of all, consequently there can be no difficulty in clearing him away if he is wrong. We do not want such nonsense as was contained in Mr. Hamilton H. Fulton's letter, which we could almost think was written at Mr. Fairlie's request, in order that the latter might have an opportunity of extinguishing the writer. There is no doubt an enormous amount of *vis inertiæ* to overcome in our railway managers in regard to anything that is new. While we cannot for a moment adopt Mr. Jones's plan of penny railway trips, we are still certain that cheaper fares and economy in working are what we must have, and if our present managers will not agree to this, they must be asked to make way for others who will move forward in this direction.

PART II.

FACTS AND STATISTICS

RELATING TO

THE FAIRLIE ENGINE

AND

LINES OF RAILWAY OF NARROW AND OTHER GAUGE

ALREADY CONSTRUCTED

IN

VARIOUS COUNTRIES.

REPORT ON VARIOUS TRIALS OF THE FAIRLIE ENGINE.

February 1870.

THE FOLLOWING NOBLEMEN, DIRECTORS, MANAGERS, AND ENGINEERS OF RAILWAYS, WERE PRESENT AT THE EXPERIMENTS AT PORTMADOC AND BRECON.

His Grace the Duke of Sutherland, accompanied by Count Szchemji, of Hungary.

Representing Russia.

Count Alexis Bobrinskoy, President of Imperial Russian Commission.

Count Zamoyski, accompanying Count Bobrinskoy.

Professor Saloff, Russian Institute of Imperial Engineers, and Member of the Commission.

M. Roehrberg Chief Engineer and Manager of the Nigree Moscow Ry &c.

M. Schuberski—Locomotive Superintendent of the Worsnesch Rostow Railway and Member of the Commission.

M. Kislinski,—Russian Imperial Engineers, Inspector of Karchof Crementchay Railway.

M. Sementechymoff, Imperial Russian Engineers, Seratoff Railway.

Representing the India Office.

Lieut.-General Sir William Baker, R. E., K. C. B.

Mr. W. T. Thornton, Corresponding Secretary, Public Works, Railway and Telegraph Department, India office.

Mr. Juland Danvers—Government Director of Indian Railways.

Representing Board of Trade.

Captain Tyler.

Representing France.

M. Genty, President of the La Vendee Railway.

M. Duval, Engineer of La Vendee.

Representing Sweden.

M. Sandberg, Engineer to Swedish Government.

Representing Norway.

M. Pihl, Chief Engineer, Norwegian Railway.

Representing Switzerland.

M. Carl Burckhardt, Engineer.

Representing N. Germany.

Mr. Mulvany, C. E.

Mr. Livingston Thompson, Managing Director, Festiniog Railway.

Mr. Fleming (Star of India) of the firm of Smith Fleming and Co. Bombay.

Mr. George Allen, C. E.

Mr. Power, Vice Chairman, Poti and Tiflis Railway.

Mr. James Samuel, C. E., Director of the Railway Working Association.

Mr. Tolme, C. E., do. do. do. do. do.

Mr. Cargill, C. E.

Mr. Preston, C. E.

Mr. Preston, Solr. London and North Western Railway.

Mr. Elias, General Manager, Cambrian Railway.

Mr. Walker, Locomotive Superintendent, Cambrian Railway.

Mr. Roberts, Engineer Brecon and Merthyr Railway.

Mr. Caulfield, Engineer Neath and Brecon.

THE FAIRLIE ENGINE ON A 1FT. 11½IN. GAUGE COMMONLY CALLED 2 FT.

The Result of Experiments on the Festiniog Railway on February 11th and 12th 1870.

February 11th.—Started from Portmadoc with the "Little Wonder" or Fairlie Engine and,

	Tons.	Cwt.	qrs.
90 Slate Wagons ...	57	10	0
7 Passenger Carriages and Van ...	13	10	0
57 Passengers ...	4	0	0
	75	0	0
Engine	19	10	0
	94	10	0

Engine double bogie $8\frac{3}{16}''$ cylinders × 13″ stroke ... ...
Wheels 2′ 4″ diameter ... ...
Pressure of steam average lb 150...
Steepest gradient 1 in 74 ...
Sharpest curves 1¾ chains ...

The total wheel base is 19 feet the wheel base of each bogie is 5 feet and the total length over all 27 feet.

On sharpest curves and steepest gradients with Engine in full gear, average speed 14½ miles exclusive of time lost in stopping and starting. Length of train 854 feet.

Generally observed that even on curves of 1¾ chains radius and at maximum speed that there was very little perceptible

oscillation or movement on the Engine, or in the carriages and by no means such as is usually felt, even on comparatively easy curves on ordinary Railways and less at high speed than at low speed. The super elevation of the outer rail on the sharpest curves was 3 inches.

February 12*th.*—Experiments with "Little Wonder" 19½ tons.
"Welsh Pony" 10 tons.
"Mountaineer" 8 tons.
to test steadiness of running on Frath Mawr Embankment.

On the "Welsh Pony" and "Mountaineer" strong vertical oscillation with less lateral oscillation.

On the "Little Wonder" when riding on the foot plates no perceptible vertical or lateral oscillation but a smooth floating movement when riding on the bogie frames, slight lateral oscillation, but less than on the other Engines.

The oscillation of the "Fairlie Engine" being confined to the bogie the influence of impact on the rails from the flanges of the wheel was far less than in the case of the "Pony" or "Mountaineer", the whole weight of these Engines being brought to bear in the course of their oscillations upon the rails.

In all the above cases the speed was confined to 10 or 12 miles an hour on a straight line on a gradient of 1 in 1,200 and the line was laid with rails weighing only 30lbs. to the yard not fished at the joints.

The "Welsh Pony" Engine weighing 10 tons with cylinders 8⅛' diameter × 12in. stroke and with wheels 2' diameter took 50 wagons loaded with slate from Portmadoc to the Engine-house, and stopped on a gradient of 1 in 85

unable to proceed further with 160lbs. to the square inch of pressure.

	Tons.	Cwts.	qrs.
Weight of 50 wagons loaded ...	123	10	0
Passengers	3	10	0
	127	0	0
Engine	10	0	0
	137	0	0

	Tons.	Cwts.	qrs.
The "Welsh Pony" then took 25 wagons weighing	59	7	2
Passengers	3	10	0
	62	17	2
Engine	10	0	0
	72	17	2

and mounted one in 85 with 140 lbs. pressure of steam in starting and 130 lbs. after running about ¼ of a mile when she was stopped to return.

The same Engine then tried with 30 wagons, could not start on a gradient of 1 in 85 but the engine-wheels did not revolve, there was therefore no want of adhesion. The load having been reduced to

	Tons.	Cwts.	qrs.
26 wagons weighing	62	6	0
Passengers	1	10	0
	63	16	0
Engine	10	0	0
	73	16	0

with an average pressure of 150 lbs. to the square inch the "Pony" took them up 1 in 85 for a ¼ of a mile at 5 miles an hour till she was purposely stopped.

The "Little Wonder" left Portmadoc the same afternoon with 72 loaded wagons weighing

	Tons.	Cwts.	qrs.
Slate trucks	138	17	2
Empty wagons	43	13	0
Passengers	4	0	0
	186	10	2
Engine	19	10	0
	206	0	2

started with 165 lbs. of steam pressure and ran to the engine-house, and up the above gradient of 1 in 85 and was purposely stopped with steam at 125 lbs. and a low fire, through the misapprehension of the engine-driver she was then backed down to the locality from which the "Pony" had started with 26 wagons and the fire having been made up and steam raised to 170 lbs she started freely occasionally slipping attained to a speed of 5 miles an hour with the 72 wagons and after running about ¼ of a mile she was increasing speed on a gradient of 1 in 100 when she was purposely stopped with steam pressure of 170 lbs. to the inch.

In the above experiments the shorter trains were standing when they were started or attempted to start partly on a curve of 4½ chains, and in the last experiment with the "Little Wonder" the train having been longer, it stood partly on a

ırve of 4½ chains radius and partly on a reverse curve of 8 ıains radius. The length of this train was 648 feet.

The weather was fine with a strong cold wind blowing ɡainst the Trains, and the rails were in a remarkably good ate for adhesion.

The Slate Waggons had no springs, the diameter of their heels was 1·6 and that of the Journals was 2¼'.

(SIGNED) SUTHERLAND.
COUNT ALEXIS BOBRINSKOY.
W. E. BAKER.
W. J. THORNTON.
H. W. TYLER.
JULAND DANVERS.

THE FAIRLIE ENGINE ON THE 4FT. 8½IN. GUAGE.

Experiments on the 14th and 15th February 1870, with "The Progress" Locomotive Engine.

"The Progress" is a double bogie Engine with a four wheeled bogie under each end. The Cylinders are 15 inches in diameter by a stroke of 22 inches. The wheels are 4′ 6″ in diameter and are coupled together in both bogie frames so that all the wheels of the Engine are driving. The wheel base is 22 feet. The grate area is 19½ feet. The heating surface is, in the fire box, 92 feet and in the tubes 1901 feet making a total of 1993 feet. The diameter of the boiler is 4′ 2″ and the tubes are 388 in number and 2″ in diameter, outside measurement. The total length of the boiler is 24 feet from tube-plate to tube-plate of the two smoke-boxes respectively. The length of the tubes is 9′ 10″. The total weight in working order when the Engine is fully equipped is 54 tons, including 1 ton 15 cwt. of coal and 2,000 gallons of water. The Engine is fitted with the Steam brake of M. Le Chatellier and with an ordinary brake applied to all the wheels. The extreme length from buffer to buffer is 32′.

On the 14th February "The Progress" left the Three Cocks Junction of the Mid Wales Railway with 39 loaded wagons and 3 brake-vans and about 50 passengers and workmen making a total weight exclusive of Engine 472 tons 6 cwt. 2 qrs. It measured 710 feet in length without the Engine. It started from the "Three Cocks" at 3·6 P. M. with 130 lbs. of steam as indicated by a Bourden's gauge. She proceeded

freely from a gradient of 1 in 2215. She passed two rising gradients of 1 in 75 the latter 29 chains long and with the above pressure, but she slipped twice on a third gradient of 1 in 75, 34 chains long and on reverse curves. After passing that gradient without difficulty and a gradient 1 in 162, she came to a stand within 50 yards of the summit of a gradient of 1 in 90, 21 chains long. The steam pressure was then 120 lbs. to the square inch. The water having fallen too near the bottom of the gauge-glass, Mr. Fairlie who was driving the Engine and was unacquainted with the gradients, applied both injectors about 30 chains from the point where the Engine pulled up at 3·35 P. M. The total distance run was 6½ miles in 29 minutes.

There was a strong wind blowing across the train with hoar frost and the rails were in excellent condition. The axle boxes of the wagons had been greased in the ordinary way. The Engine was unable to start the train after it stopped, though the pressure had been increased to 150 lbs.

On the 15th February the "Progress" left the "Three Cocks" at 10h. 47m. 30s. with 140 lbs. of pressure and with a load of 40 wagons and two vans and about 30 passengers. The train was 720 feet long and weighed exclusive of the Engine 476 tons.

She proceeded freely to the water-tank 3 miles from the "Three Cocks" and stopped there at 11h. 0m. 30s. with 115 lbs. of pressure. But the tank having been partly frozen no additional water could be obtained by the trough. She started again at 11h. 6m. 30s. with 125 lbs. pressure and went

straight forward to Builth, passing Erwood 7 miles from the "Three Cocks" at 11-27. She reached Builth, 14 miles from "Three Cocks" at 11h. 50m. 30s. She did not slip between "Three Cocks" and Builth. She passed the point at which she had stopped on the previous day at 8 miles an hour and with a pressure of 140 lbs. to the inch. The Engine on this day was driven by Edward Williams under the supervision of Mr. Greenhow the Locomotive Superintendent of the Mid Wales Railway.

(SIGNED) SUTHERLAND.
COUNT ALEXIS BOBRINSKOY.
J. ZAMOYSKI.
W. J. THORNTON.
H. W. TYLER.
JULAND DANVERS.

On the 15th February, the "Progress" left Tall-y-llyn at 2h. 15m. 30s. with 13 loaded wagons and 2 brakevans weighing altogether 151 tons 17 cwt. 0 qrs. and with a steam pressure of 125 lbs. After running for 3 miles for the most part on a descending gradient of 1 in 40 she was brought to a stand at Talybont station, where her tanks were filled. She started from Talybont at 3h. 13m. with a pressure of 140 lbs. and ascended a gradient of 1 in 35 for half a mile. She then mounted a gradient of 1 in 38 for 6⅝ miles and passed the summit of that gradient at 4h. 16m. 15s. with 120 lbs. of pressure. She passed through the tunnel 660 yards long on a rising gradient of 1 in 68 in 2m. 15s. and was stopped at the Torpantau Station at 4h. 18m. 30s. the pressure continuing the same. This portion of the line

contained curves of varying radius on the rising gradient of 1 in 38 the train having sometimes been passing over reverse curves.

The water gauge burst at 4½ miles from Talybont and the engine-driver Edward Roberts (who was acting under the superintendence of William Barker) was without any means of ascertaining the state of the water in the boiler inasmuch as there were no steam-cocks on the boiler. The Engine did not slip at all on the 15th. The weather was fine and dry as on the 14th but with more sunshine and rather less wind.

Agreed to same evening by all who witnessed the experiment.

(SIGNED) SUTHERLAND.
COUNT ALEXIS BOBRINSKOY.
J. ZAMOYSKI.
W. J. THORNTON.
H. W. TYLER.
JULAND DANVERS.

SECOND SERIES OF EXPERIMENTS WITH THE FAIRLIE ENGINE ON THE 1 FOOT 11½IN. GAUGE.

The result of an experiment on the Festiniog Railway on the 16th February 1870 with the "Little Wonder" (Fairlie Engine.)

Length of Engine	27 feet.
Weight of Engine in steam ...	19½ tons.
Diameter of cylinder.....	8 3/16 inches.
Length of stroke	13 inches.
Two four wheel bogies.....	
Diameter of wheels 2′ 4″	
Wheels coupled in each bogie.	
Wheel base of each bogie.....	5 feet.
Total wheel base	19 feet.

Description of Load.

		Tons.	Cwt.	qrs.
22	Wagons of coal	64	18	0
21	Wagons of slates	49	3	1
2	Bogie timber trucks (carrying timber) in length 42 feet	4	18	2
	Passengers weight	1	1	2
2	Empty trucks between timber bogies	1	4	1
1	Workmens carriage.....	0	12	0
	Engine	19	10	0
	Total.....	141	7	2

Length of train with Engine 407 feet.

The whole distance to be run over from Portmadoc to Dinas 13¼ miles having a total rise from sea level of 703 feet with maximum gradient of 1 in 74 and average gradient of 1 in 92 for 12¼ miles. The Traethmaur Embankment near Portmadoc of 1 mile in length being practically level. The maximum curves 1¾ chains.

Average curves being 6, 7 and 8 chains. The whole of the Line being composed of a succession of curves with the exception of the before named Embankment and three or four other short portions.

The Train started from Portmadoc at 5-41 P.M. At Penrhyn Station 5-58 without stopping there.

Arrived at Hafod Llyn Station at 6-18 where it stopped 8½ minutes.

Started at 6-26½ arrived at Dduallt Station (Watering place) at 6-40, stopped 15 minutes on account of water being frozen the Tank could not be filled in the usual time.

The Train reached the long Tunnel at 7-2 P. M. through which it passed in 2m. 10s. (length of Tunnel 730 yards). Ran up to Tanygresion Station at which it arrived at 7-9 passed it slowly without stopping, arriving at Dinas at 7-15 having made the entire journey in 1h. 34m. including stoppages or exclusive of stoppages 1h. 10½m.

Maximum speed 15 miles an hour.

Average speed 11¼ do.

The Engine during the journey from Portmadoc to Hafod Llyn never slipped.

On starting from Hafod Llyn Station a slight slipping occurred (the train being on a curve of 4 chains with an inclination of 1 in 111) the rails being wet and greasy.

Slight slipping on starting from the watering place at Duallt.

The Engine slipped three times in passing through the tunnel, the rails being wet throughout.

Considerable slipping took place at the junction of Branch Line, this place being always wet and greasy owing to the slate trains waiting for the down passenger train.

The pressure of steam ranged from 160 to 180 lbs. at which latter pressure the train started, the pressure being on one occasion only 145 lbs. for a quarter of a mile average pressure 175 lbs.

The entire journey was ran throughout by the Engine in "two-thirds gear."

There was a head wind during the whole of the Journey such being very strong in some parts of the Line against the Train.

(SIGNED) LIVINGSTON THOMPSON.
C. E. SPOONER.
COUNT ALEXIS BOBRINSKOY.
T. ROEHRBERG.
PROFESSOR SALOFF.
R. VANDESEN.
J. SEMENTSCHINOFFE.

THIRD SERIES OF EXPERIMENTS WITH THE FAIRLIE ENGINE ON THE 1-11½ GUAGE UNDER THE SUPERINTENDENCE OF THE PRESIDENT AND ENGINEER OF THE LA VENDEE RAILWAY OF FRANCE.

Started from Portmadoc with a train of 140 empty slate wagons and 7 loaded coal wagons gross load 100 tons 16 cwt. 2 qrs. length of train 1323 feet and proceeded to Dinas the upper end of the Festiniog Railway. The maximum speed was 16½ miles the average 12½ miles.

On the return journey the speed attained was 30 miles an hour over many portions of the road, the average speed being 25 miles an hour.

Extract from Engineering Dated 22nd April 1870.

The Fairlie system in Russia. The Commission of Russian Engineers who lately visited England for the purpose of seeing Mr. Fairlie's narrow gauge railway plant, and the Festiniog Railway where; his Engines are at work, have according to the "Iron and Coal Trades Review" reported strongly in favor of the system. They recommended it to be adopted for a portion of the railway between St. Petersburg and Moscow, and estimate the cost of construction at about £4,500 per mile.

Extract from the Engineer Dated 21st January 1870.

A double bobie eight wheeled 24 ton Fairlie Engine, built for the Nasjo and Oscarsham Railway in Sweden; was tried on Monday on the Ring Railway of the Fairlie Engine and Steam Carriage Company at Hatcham, in the presence of the Duke of

Sutherland, and about forty gentlemen, and practical Engineers. The Engine was run round the curves of 50ft. radies, at the speed of twenty miles an hour, with the same ease as the passenger Steam Carriage, the remarkable performance of which we noted in July last year.

THE FESTINIOG RAILWAY.

NOTICE No. I.

(The Engineer, Sept. 24, 1869.)

We have during the last five or six years invariably, if not continually, advocated the extended adoption of what has come to be known as the "light system" of railway traffic. Our views on this subject have been persistently disputed by writers who we believe lacked any practical experience in the working of railways of less gauge than 4ft. 8½in.; but, on the other hand, it is worth bearing in mind that not a few of the most eminent engineers of the day have admitted that opinions similar to those we have expressed were perfectly correct; while a still more numerous body, conceding that the narrow gauge—a feature in the light system—was right in theory, reserved their judgment until some practical results in its favour had been obtained. We do not propose here to re-open the entire question, nor shall we do more than allude to the fact that an essential portion of the light system consists in working 4ft. 8½in. gauges with combined steam carriages. For the present we shall confine ourselves to the consideration of the merits of narrow gauge lines for local and branch traffic, and in doing so we believe we shall be able to place before our readers certain facts which may tend to modify the opinions of even our most persistent opponents.

Before proceeding further, it will be as well to put on record here, in the most compact form possible, the arguments urged for and against narrow gauge railways. In favour of narrow gauge railways, we state that their cost of construction is very small as compared with that of ordinary lines; that the expenses for maintenance are very moderate; that the proportion which the dead weight moved bears to the whole load rapidly diminishes with the width of gauge; that a high rate of speed may be maintained with safety on narrow gauge lines; that very sharp curves may be traversed with safety when the rails are close together, which could not be traversed at speed at all if the rails were more widely spaced; that narrow gauge can be used with safety and success for the carriage of passengers; and, lastly, that narrow gauge lines can be constructed and made to pay in districts and under circumstances which preclude all hope of a dividend from railways of ordinary dimensions. Our opponents urge, on the other side, that it costs as much per mile, within a mere trifle, to make a railway of 2ft. or 2ft. 6in. gauge as to make one of 4ft. 8½in.; that speeds greater than ten or twelve miles an hour are inadmissible on very narrow roads; that it is just as dangerous to traverse very sharp curves on the narrow as on the broad gauge; that no saving whatever can be effected in the cost of conveying a ton of goods or passengers a mile; that narrow gauge roads are behind the age, and, finally, that wherever there is room for a railway at all it should be made full size. This is, we think, a fair exposition of the arguments for and against narrow gauges. It is indisputable that of late a very strong feeling in favour of cheap railways has sprung into existence in the minds of men of high position and great influence. The accuracy of the principles we have indicated, and the recognition of which in practice we have advocated, is beginning to be recognised. Popular feel-

ing tends to turn stongly to our side, and under the circumstances we make no apology for placing before our readers, at considerable length, particulars of the construction and working of the narrowest railway, carrying passengers, in the world, convinced as we are that such facts as we shall adduce possess an enormous importance for those who would develope the resources of the country by providing better and more complete means of intercommunication. This narrowest railway is that which unites Port Madoc, in North Wales, with Festiniog and its slate quarries. Within the last week we have gone over this line four times, and thanks to the courtesy of Mr. C. E. Spooner, C.E., the engineer of the line—which was constructed by Mr. Spooner's father—we were supplied with every possible facility for making ourselves acquainted with the construction of the line, and of the engines, &c., working it. As to the mode of working, and the results obtained in working, we were placed in a position to obtain the fullest information which could be obtained. Most of our readers have, no doubt, heard of the Festiniog Railway, and believe, or more properly think, up to this moment that it is nothing more than a horse tramroad on which a couple of rough little colliery locomotives have been put to work. We beg them at once to disabuse themselves of this notion, which has no foundation in fact. TheFestiniog Railway is a miniature line, the working arrangements of which are modelled on those of other lines in the kingdom. The signals, the stations, the engines, the carriages, and the rolling stock generally, are equally in finish, and perhaps superior in efficiency, to that of any railway in the kingdom ; while the permanent way, now being rapidly relaid by Mr. Spooner, is in finish, quality, and system of construction, equal to that of any line in the world in its way.

On the 11th of April, 1865, Captain Tyler (Government

Inspector) read a paper before the Institution of Civil Engineers, entitled "On the Festiniog Railway for Passengers; on a 2ft. gauge, with sharp curves, worked by locomotive engines." To this paper we are endebted for some particulars of the first life of the line. Captain Tyler described what he saw in 1865, but the energy of Mr. Spooner and his directors has wrought many great changes in the last four years, and even Captain Tyler would find a second visit to the Festiniog Railway fully repay him for the trouble of going to it—a tedious journey enough, it must be admitted.

The Festiniog—or, to spell it Welsh fashion, the Ffestiniog—Railway was constructed about the year 1832 as a horse tramroad. It commences at the quay of Port Madoc, crosses an embankment made by a gentleman, who ruined himself by the undertaking, to reclaim a large waste of slob land from the sea, and runs for thirteen miles through a country the wild magnificence of the scenery in which can scarcely be equalled even in Wales, to the hamlet of Dinas—pronounced Deenàs—in the district of Festiniog. Here it branches out into four or five lines, which ascend by gradients varying from one in five to one in three-quarters, to the slate quarries in the Festiniog Mountains. It is almost needles to say that these branches are worked neither by engines nor horses; they are self-acting inclines, on which the full slate wagons running down hand up the empties by means of a wire rope and drum. Of these inclines, and the quarry system of Festiniog in general, we shall have a good deal to say at another time. The trains are made up at the foot of these inclines, and collected at Dinas to be conducted by locomotives to Port Madoc. The line is on an ascending gradient the whole way—there is not so much as one yard of level. The average rise is 1 in 92 for twelve and a-half miles. The steepest

gradient over which passengers are carried is 1 in 79·82; but some portions of the collecting lines at Dinas are worked by locomotives over a gradient of 1 in 60. The Traeth Mawr embankment, before referred to, about, 900 yards long, is nearly level, rising slightly towards Dinas. It is not practicable, by any possible kind of writing, to give an accurate idea of the nature of the country traversed. The line follows the Vale of Festiniog, being scarped out of the mountain side. Ravines, have been bridged over or crossed by what are known as breast-wall works. In not a few places it is possible, standing on the engine, to kick a shoe down a sheer depth of 100ft.; in others, ravines are crossed by embankments of dry stone not more than 10ft. wide at the top and at least 60ft. high. If we were asked to draw a plan of the line from memory we should simple repeat the letter S many times. A modarately long train may be on three curves at once. The sharpest curve, nearly a half circle, is 1¾ chains radius, and the others vary from 2¼, 2½ 3¼, to 5 chains, &c. The line has recently been modified, as far as practicable, by Mr. Spooner, all the curves having been rendered parabolic, which system, although it renders them sharper in the middle, makes the entrance excessively easy. The fact that although the line has been worked by locomotives for six years, no train or engine has ever been off except twice, when the points were left open by the negligence of a signalman, and when no injury whatever was done to either rolling stock or passengers, is admirable testimony to the success with which the parabolic system has been adopted. There is one tunnel sixty yards long, and another 730 yards long; the first cut through shale, and the latter through syenite rock. These tunnels are so small that they barely permit the engines to pass through. A tall man standing on the foot-plate must crouch that his head may clear the roof, and woe to him if he allows

a hand or a foot to hang out beyond the width of the engine, which clears the tunnel by about 4in. only at each side. The permanent way is partly old, partly new. The renewal is rapidly being carried out by Mr. Spooner. The old portion consists of single-headed rails, without any bottom flange—T this section—weighing 30 lb. to the yard. They are in length of 18ft. to 21ft., laid in 10 lb. chairs spiked to cross sleepers. The new rails weigh about 48½ lb. per yard, are 24ft. long, and are fished at the joints by a very ingenious fish-plate, which we shall illustrate in another impression. The joint chairs are carried on a square sleeper frame. The whole arrangement is very clever, reflects much credit on Mr. Spooner, and leaves the rail as strong at the joint as anywhere else.

The rolling stock has been considerably modified since Captain Tyler wrote his paper. In the third-class carriages the passengers are still carried back to back, but the first and second-class resemble ordinary carriages in every particular. One first-class carriage which we measured may be taken as typical of the rest. It was fitted with four seats, each seat holding three passengers. The height in the centre is 5ft. The length of the body is 9ft. 6in. The length of each compartment is 4ft. 6in., and the height from the floor to the seats is 1ft. 2in., to which the cushion must be added. The breadth over all is 6ft. 3in. The wheels are 1ft. 6in. in diameter, fitted with volute springs. The axle-boxes are got at through doors in the seats, and can be easily oiled and examined. The weight of the carriage complete is 30 cwt. only; the buffers are central. The slate wagons are of two kinds, one "small," weighing 13 cwt, and holding about two tons of slates; the other "large," weighing 17 cwt., and holding three tons of slate. They have open work angle iron sides and boarded bottoms. The follow-

ing are the dimensions of one which we measured :—Length, 6ft.; width, 2ft. 11in., depth, 1ft. 6in.; wheels, 1ft. 6in. diameter fast on the axles; wheel base 3ft. 2in. long. Wagons are also used for the conveyance of goods, ballast, casks, &c. The following are the dimensions of one from actual measurement:—Length, 7ft. 6in. ; height, 2ft. 11in.; width, 2ft. 11in., all inside body; height from rail, 5ft. ; wheels, four, loose on axle, 1ft. 6in. diameter; wheel base, 3ft. 8in. There are also powder wagons, arched top coffers of ¼in. iron plate, 6ft. long, 3ft. wide, and 3ft. 6in. high. Brake vans, timber trucks, and covered goods wagons, all resembling in miniature those found on ordinary lines ; and besides these, a set of cars for the quarry men, and a machine known on the line as "the boat," which looks like a slice off the bows of a wherry, mounted on four high wheels. There is a tradition that this was used by a lady holding property on the line to come down the incline to Port Madoc.

At the time Captain Tyler wrote there were only four engines on the line, there are now eight. The first four were built by Mr. George England, of the Hatcham Ironworks, New Cross. They weigh full 7½ tons. They have four coupled wheels, 2ft. only in diameter. The cylinders are outside the frame. Subsequently two other engines were built by Mr. England, weighing 10 tons full, with 2ft. wheels and 8in. cylinders, 13in. stroke. The working pressure is 160lb., but 200lb. have been carried. Messrs. Manning and Wardle supplied a seventh engine, used altogether on a branch at the Festiniog end. Within the last few weeks an eighth engine has been added, "The Little Wonder." It was also built at Hatcham. It is a double bogie engine, designed by Mr. Fairlie. The boiler is of steel, with a mid-feather across the fire box. The following are the particulars of the "Little Wonder": Diameter

of cylinders, 8¼in.; length of stroke, 13in.; diameter of wheels, 2ft. 4in.; diameter of boiler, 2ft. 6in.; length of barrels, 7ft. 6in.; length of fire box, 6ft.; width of fire box, 3ft.; height of fire box, 4ft. 6in.; length of copper fire box, 5ft.; width of copper fire box, 2ft. 6in.; height of copper fire box, 3ft. 6in.; grate area, 11 square feet; heating surface, 60 square feet; heating surface of tubes, 670 square feet; total heating surface, 730 square feet; number of tubes, 218; diameter outside, 1½in.; length, 7ft. 10in.; capacity of tanks, 90 gallons; coal bunkers, 15 cwt. The working pressure is 160lb. The length of the engine over all is 27ft., and its weight, in working order, is twenty tons, carried on eight wheels; so it will be seen that Mr. Spooner is getting on. After carefully testing this engine, we came to the conclusion that whatever may be said by its opponents, of the Fairlie system for main line traffic, it is exactly the thing for narrow gauge work. In order to ascertain exactly what its performance is, we went over the line twice on the "Little Wonder," and twice on one of the old 10-ton engines, the "Little Giant," with results which we shall now proceed to give.

At a little after 1 p. m. on Saturday last, the "Little Wonder" left Port Madoc for Festiniog in such a storm of wind and rain as we do not care to encounter again. She had behind her a train consisting of—

	Weight. tons	cwt.	Length. yards.
111 Slate wagons	74	0	287
6 Carriages	9	0	22
60 Passengers	4	10	—
12 Goods wagons	26	6	30
	113	16	339
Add the engine	20	0	9
	133	16	348

Thus we have a total load of 133 tons 16 cwt., and a total length of train, 348 yards. This train the engine took with much ease up to Halfodllyn, a distance of seven and a-quarter miles, over the worst part of the road. Not far from Halfodllyn the long tunnel already referred to commences, and after consultation it was determined to take off some of the slate wagons, as it was feared the engine would get stalled in the tunnel by slipping; and as no one can get off the engine or get out of a carriage, the tunnel is a peculiarly nasty place in which to stick even for a minute. All the wagons might have been left on, however, as the engine rushed through with the slightly diminished load in one minute and five seconds, or at the rate of twenty-three miles per hour nearly. The return journey commenced about three-quarters of an hour after the experimental train arrived at Dinas. Only a few slate wagons were on in addition to the passenger train; over the new portion of the road a speed of over twenty-five miles an hour was attained with ease, and on one occasion a velocity of about thirty-five miles an hour was reached, the bogie engine swinging round the curves with graceful ease and a total absence of strain or jerk. We did not take the time spent in running to Halfodllyn, but from Halfodllyn to the beginning of the embankment, a distance of a little over six and a-quarter miles the time was as follows:—Started from Halfodllyn at 4.6 p. m., stopped at Penrhyn at 4.20, started again 4.24. Stopped to take tickets at end of embankment at 4.30. Total running time 19 minutes, equivalent to 19·74 miles per hour. It is worth while to consider here the nature of the work done by the engine when running at twenty miles an hour. During each minute the train passed over a distance of 1760ft. and, as the wheels were 2ft. 6in. in diameter, they made 240 revolutions per minute, a velocity increased during many portions of the run to as much

as 360 revolutions per minute; but even at this tremendous speed—corresponding to a velocity of about ninety miles an hour for a 7ft. wheel—the engine ran with an almost total absence of oscillation, nor did the bearings heat in the slightest degree. A speed of ninety miles per hour has never yet been attained on any railway, and up to the present moment it follows that the narrow gauge has beaten the ordinary gauge in its relative power of transporting passengers at high velocities. Nor is it to be assumed that thirty-five miles an hour is a limit which cannot be exceeded. It is to be borne in mind that the Festiniog engines are really goods engines in relation to the road on which they run. The "Little Giant," with 2ft. wheels, works under just the same relative conditions as a 4ft. 8½in. engine, with 4ft. 8½in. wheels. No one expects an express speed from such engines; but there is no good reason why the Festiniog line should not be worked with 3ft. wheels, that is to say, a gauge and a-half high—a proportion adopted in many of the best engines of the day, which have driving wheels 7ft. 1in. in diameter.

In the face of the facts we have placed before our readers, it must be admitted that high velocities are not inadmissible on the narrow gauge. Why they should not be, and many other points connected with the Festiniog line, we must reserve for another article.

NOTICE No. II.

The Engineer, 1st October 1869.

We have stated that in order the better to master the details of the working of the Festiniog and Port Madoc Railway we traversed it from end to end four times, twice on Mr. Fairlie's engine the "Little Wonder," and twice on one of the old

pattern engines, the "Little Giant." The results of the first two trips we gave in our last impression; we have now to place before our readers those of the other two.

We left Port Madoc shortly after eight a. m. on the morning of Monday the 20th instant, and reached Festiniog, or more properly Dinas, in about an hour and a-half, including, of course several stoppages on the way. The train consisted of forty-one slate trucks, empty, five passenger carriages and a brake van, one bending machine,* and the "boat" before referred to. The weight of the whole, including thirty passengers, was fifty-one tons, or with the engine sixty-one tons. Steam was maintained with much ease at 160 lb. in the boiler. The manner in which the little engine with its 2ft. wheels, crept, caterpillar-like, up the steep road was remarkable enough to unaccustomed eyes. The first two or three miles proved pretty clearly, however, how great a step in advance, how much real progress, Mr. Spooner had made when he put the double bogie on his line. The "Little Giant" shoulders her work in a very curious fashion. She gets over the road not steadily, as she should do, but by a series of efforts rapidly repeated. As each cylinder alternately drives the engine by the pressure on the forward cylinder lid, that side advances before the other by a distance perceptible enough to any one on the foot-plate at slow speeds, the head of the engine sidling across the rails, while at high speeds there is all the lateral oscillation that at one time earned for certain engines the title of "boxers." From the great length of overhang at the fire-box end, again, the engine jumps most unpleasantly, although the little tender, carrying coal only is coupled up as tightly as possible to the foot-plate. Over

* This is a very ingenious machine of Mr. Spooner's invention, which we shall describe fully when the patents are completed.

the old portions of the road a speed of eight or nine miles an hour is the greatest at which it is possible to run without incurring the risk of breaking the springs, or loosening the driver's teeth. In the double engine, as a matter of course, nothing of this kind is felt owing to the length of wheel base ; nor is there any shouldering or lateral oscillation due to the action of the steam on the cylinder covers, because, in the first place, the mere length of the machine tends to act as a corrective, and, in the second, because the two engines never beat together, except by accident for a few seconds. As will be seen, the load taken up by the Little Giant was less than one-half that taken by the double bogie engine. It must not be understood that fifty-one tons is the maximum load for the lighter engine, as many as eighty tons having been taken on a pinch ; but it was certainly quite as many as she could keep steam for comfortably at ten or twelve miles an hour. The double bogie engine is probably not more heavily loaded with 130 tons than the Little Giant is with sixty tons; and when the former has come to her bearings and worn herself smooth she will probably be quite up to loads of 140 tons, including her own weight. The question is here purely one of keeping steam, and this again depends not a little on the relative efficiency with which the steam is worked in the cylinder. The Little Wonder has a considerable advantage in the greater height of wheel, which reduces the waste per mile due to clearance and port space. It did not fail to strike us that the ordinary engines are underpowered, as far as economy is concerned, for loads of fifty tons. It is impossible to expand steam in their cylinders to any appreciable extent ; the noise of the exhaust, indeed, resembles revolver firing more than anything else. With a more powerful engine and more cylinder room, coal could not only be burned more econmically

but the steam used to more advantage. The strain on the engine would be reduced, the back-pressure diminished, the fire less cut up, and, in a word, coal bills generally kept down. Of course if the loads to be hauled had remained very moderate, the single engines would have answered every purpose. They were designed to haul about thirty-five tons at ten miles an hour, but loads have not remained moderate. On the contrary, as we shall show presently, they have augmented, and are augmenting daily. It is very easy to build engines which will suit a narrow gauge line, so long as the loads are kept to narrow gauge proportions ; but when we find loads approximating to those carried on the 4ft. 8½in. gauge thrown upon the 2ft. gauge the problem does not admit of such easy solution. Now it is pretty good work for an ordinary locomotive to take fourteen carriages weighing, filled, about 120 tons, up a gradient thirteen miles long, rising at the rate of one in ninety-eight, and abounding in curves of from four to five chains radius, at thirty miles an hour. Yet the "Little Wonder" actually did this duty, the speed being reduced somewhat in the relative proportions of the gauges, this reduction of speed being, of course, a natural consequence of the reduced weight of the engine. A locomotive weighing twenty tons with coal and water, and having less than 700ft. of heating surface, cannot be expected to do as much work as an engine with 1,100ft. of surface and weighing over thirty tons without coal and water. With the 2ft. gauge especially, and on lines curved anything like the Festiniog Railway, the only solution of the problem lies in the adoption of four cylinders, for the very same reasons as those which led to the adoption of four-cylinder engines on the Chemin de fer du Nord, and some other lines conveying goods and minerals in trains too heavy, in one sense, for the gauge. In the selection of the proper class of locomotive for any line

will lie one great element of economical working; but the selection of the right kind of rolling stock for lines like that under consideration is a matter of the most vital importance. We shall probably astonish many of our readers when we tell them that the consumption of fuel up to the present time has amounted to a little over 50 lb. per train mile, or about double that of an ordinary well-proportioned passenger engine. This fact may appear at first sight to tell heavily against the whole system; but a little examination will show that the 50 lb. a mile is subject to many and important deductions. In the first place, it includes the entire consumption of fuel standing as well as running. Each engine is under steam about fourteen hours a day. The actual running time out of this is about three hours only; during the remainder the engines are either shunting in the yard, standing under steam, or making the return journey down the incline, during which the fire has of course to be kept up, and generally speaking the blower on. The true working consumption it is obviously very difficult to get at. As nearly as we could ascertain 3 cwt. of coal will take the "Little Giant" up to Dinas with fifty tons behind her, and down again to Port Madoc, which is equivalent to about 22 lb. per mile going up. This is too much, however, and admits beyond doubt of considerable reduction, first by improving the permanent way, and secondly by augmenting cylinder space by using four instead of two cylinders, and so giving the driver a chance to work his engine somewhere but in nearly full gear. The coal, too, is nothing like so good as that used on first-class lines—a matter which deserves consideration when we come to compare the relative efficiency in fuel of several different engines. Considerable advantage, too, would beyond question result from an augmentation in the diameter of the driving wheels. They should under no circumstances be less

than 2ft. 6in. high; 2ft. 9in. would perhaps be better, the tractive force being kept up by proportionally increasing the length of stroke. But above and beyond all this it must not be for a moment forgotten that the Festiniog line cannot be taken as a fair sample of what an extended system of lines on the 2ft. or 2ft. 6in. gauge would be. It passes, as we have already explained, through an impossible country; and the excessive, and beyond measures vexatious, rules as to head way and side way to which Mr. Spooner has had to conform no doubt place the system at a great disadvantage. As an example, we may adduce the fact that low as the engine wheels are, the engine funnels are excessively short, and even now hardly clear the roofs of the tunnels or the soffits of the accommodation bridges across the line. This reduction in chimney length tells of course on the draught, renders an otherwise excessive use of the blower indispensable, and is accompanied of necessity by a reduction in the diameter of the blast pipe which cannot fail to increase considerably the consumption of fuel.

Of our fourth trip, from Dinas to Port Madoc, little need be said, as the engine had no work to do, descending with the trains almost altogether by gravitation. The same disagreeable jumping motion was of course apparent; but although running tender first, the curves were taken with remarkable ease and steadiness on the new track, and a speed of about fourteen miles an hour there maintained without undue oscillation.

In our last impression we referred to the rail joint used by Mr. Spooner. The fish-plate, grips the lower flange, and the practical result is that not only is the line stiffened, but the nuts lose their tendency to turn back. The sleepers are arranged in the form of a square framework. We may add that we have never had the fortune to run over a better jointed road than Mr. Spooner's.

As the working expenses of such a line as that under consideration, cannot fail to present questions of interest, we are pleased to be able, thanks to Mr. Spooner, to place the following facts before our readers. They show clearly how enormously the traffic has increased of late, and of what so narrow a line is capable. It may be as well to premise that at present but six trains each way are run in the day, but the number can be doubled without inconvenience. The accounts are at present only available for our purpose to June 1868, the report for 1869 not yet being made public. For the year ending June, 1868, the working expenses were as follows :—Maintenance of way, £1069 15s. 8d. ; masonry, £104 17s. 8d. ; locomotive department, £699 16s. 7d. ; tonnages, £1222 11s. 9d. ; station-masters and staff, £2353 3s. 6d.; salaries £264 4s. 10d.; parish rates, £779 9s. 6d. ; passenger duty and income tax, £382 9d.; general charges, £266 4s. 1d. ; timber, coal, and iron, £1980 14s. ; rolling stock, £1072; total, £9694 18s. 6d. The total receipts amounted to £22,852 13s. 5d. The working expenses, therefore, came to about 42 per cent. of the income; and it will be noticed that in the working expenses are included income and other taxes, and a toll to the Tre-Madoc estate and Mr. Bankes for crossing the Traeth Mawr embankment. The average proportion borne by working expenses to receipts on English railways, in general is 48 per cent. It will, therefore, be seen that Mr. Spooner works, perhaps one of the most difficult roads in the world, at a price so much lower than the regular rate that, could all English railways be worked at the same cost, high dividends would be the rule and low dividends strictly exceptional; and there can be no doubt whatever that when Mr. Spooner has relaid his roads, got better engines, and ceased to charge to working expenses what most directors would charge to capital, the working expenses of the Festiniog

Railway will be still further reduced. As regards the development which the traffic has undergone, we cannot do better than use Mr. Spooner's own words.

"The accounts," says Mr. Spooner in his report for 1867-68, "that I have the pleasure to submit the proprietary for the past year, ending 30th June, show a large increase of traffic over that of the preceding year. The quantity of slates carried over the line amounts to 112,051 tons 19 cwt., and carriage of merchandise 14,693 tons 11 cwt. 2 qrs. making together 126,745 tons 10 cwt. 2 qrs. The total receipts for the twelve months amounted to £22,852 13s. 5d., and the money value of increased stock to £5655 14s. 3d. The expenditure was £17,871 6s. 5d. The increase on carriage of slates, as compared with the past year, is 18,278 tons 19 cwt., productive of £2401 8s. 7d.; merchandise traffic, 903 tons 11 cwt. 2 qrs., productive of £242 15s. 6d.; and passenger traffic £714 4d. The increase of train mileage was 2449, or as 46,732 miles run for the past year to 44,283 for the year ending 30th of June, 1867. The two locomotive engines ordered last year, together with railway bars and fish-plates, have been paid for, as appears by the accounts; such new rails and plates are sufficient for two and a-half miles of line, three-quarters of a mile of which have been laid to permanent way. In consequence of the additional numbers of inclined planes at the various slate quarries beyond the upper termini of your line, and the increase in the production annually of slate, there has arisen the necessity of a larger stock of slate wagons, and a considerable addition to the annual expense of repairs at the company's works. As there is every probability of a progressive increase in the traffic, it is important that an ample supply of slate wagons and other rolling stock be maintained to meet it."

We now come to the most important fact of all. At the annual general meeting held in August, 1868, a dividend of no less than 6 per cent. for the half-year was declared. Hear that, ye holders of ordinary railway stock! 12 per cent. per annum from railway property! Why is this result obtained? Simply because the line which gave it was cheaply made and is cheaply worked. It is adapted to its purpose; it is not too big for its traffic. Instead of 40-ton engines and tenders we have engines and tenders of a fourth of the weight. Instead of first-class carriages weighing 7½ tons, and accommodating thirty-two passengers, representing 4¾ cwt. of dead weight per passenger, we have carriages weighing 30 cwt., holding twelve passengers, or 2½ cwt. per man; and advantages similar in character hold good of all the passenger vehicles. Then we turn to the goods stock, what do we find? Slate trucks weighing 17 cwt., holding three tons, and coal and other trucks in which the proportion of dead to paying load is about the same. On the 4ft. 8½in. guage eight tons of coal, &c., are commonly carried in trucks weighing 4 tons 6 cwt., 4 tons 11 cwt., &c., On few ordinary lines does the paying load exceed the dead weight by more than three-fourths. We shall not prolong our account of the Festiniog line by showing why it is that the dead weight must increase in a very rapid proportion with each increase in guage. One fact is worth a bushel of theory it is said, and the Festiniog Railway affords the best possible proof that a reduction in guage to a little less than one-half that which is normal to Great Britain, permits a reduction in the weight of rolling stock as compared with a load of the utmost possible importance to the proprietary.

We do not wish to be misunderstood even for a moment. We do not pretend that all the lines in England would have

been better had they been constructed to a 2ft. gauge. Far from doing so, we state explicitly that we consider the 2ft. gauge too narrow for any line. In order properly to develope the resources of this great country two systems of railway are apparently indispensible. First-class or main roads of comparatively wide gauge, and feeders of narrow gauge. Were the railways of this country to be laid out again, we should advise the construction of such roads as the London and North-Western, Great Northern, &c., to a 5ft. gauge. There is not much to complain of about the 4ft. 8½in. gauge, but there is a little. It is too narrow to permit locomotives with large inside cylinders being placed upon it, unless the valves are turned over the tops of the cylinders, or set at an objectionable angle, and it rather limits the diameter of the boiler. Now the extra 3½in. gained by adopting 5ft. instead of the normal gauge, would just have disposed of this difficulty, and enabled locomotive superintendents to arrange all their machinery without trouble. For the feeders we should adopt a gauge of 2ft. 6in., precisely half that of the main lines; and on these feeders the speed might be half that observed on the main roads—say sixteen to twenty-two miles per hour. The great error hitherto committed in constructing feeders has lain in making them out of all proportion too big and heavy for their traffic; and this mistake has no doubt arisen from the belief that great evils would be entailed by asking passengers to change carriages. But as a matter of fact, this difficulty has not been obviated by the adoption of the 4ft. 8½in. road. The direct effect of the operation of this mistaken belief in the necessity for "oneness" of gauge has brought about numerous evils. The resources of half the country are not developed. Capital which might be beneficially invested lies idle, or is spent in absurd schemes. Who will take in hand the introduction of a second series of railways to a 2ft. 6in.

gauge to feed main lines? Who will obtain from Parliament the repeal of the most stupid bill ever passed, rendering the construction of lines less than 4ft. 8½in. for passenger traffic illegal? Neither the day nor the man may yet have come; but our readers may rest assured that with the advent of both, a new time of prosperity will dawn on the existing railway world, and the blessings of ample facilities for intercommunication will be conferred on towns and districts now, in a sense, beyond the pale of civilisation.

We do not write this simply because the Festiniog Railway is a success—far from it. The Festiniog Railway and its working only prove in a very practical way certain great truths which have not yet received the recognition which they deserve. Even though the line were, commercially speaking, a failure, the failure would not alter mechanical laws. Engineers who have studied the subject in all its bearings have long since seen that by properly proportioning the rolling stock to the road it is as easy to work a 2ft. gauge with safety as one of double or treble the width. But there are certain men and certain minds which cannot understand mechanical truths unless they are presented to them in a very matter-of-fact form. The Festiniog Railway supplies the only manner of proof which these gentlemen can understand. There is, besides, a large section of the public, which, knowing nothing of the reasons which lead up to the adoption of different systems of construction, judge of the merits of these simply by the results. For both classes we have especially written this and the preceding article on the same subject. If we have shaken a prejudice, or convinced a waverer, or induced one man of talent and experience to believe that there is more in narrow gauge railways than was dreamt of in his philosophy, then have we not written in vain.

In conclusion, we have to state that we have receive letter from Mr. Spooner, correcting one or two slight inac racies in our last impression. The Festiniog Railway Compa possess no slate or other wagons with loose axles. Those saw belonged to quarry companies. The long tunnel cle the sides of the locomotives by a distance of from ten to fifte inches. In the upper parts of the road where wall and ro approach to within five inches of the engine, changes and mo fications will soon be made giving more room. The Festini Company possess several coal trucks larger than those the c mensions of which we have already given. These last are 9 3in. long, 4ft. wide, and 3ft. deep. The wheel base is 6ft. a the wheels are 18in. in diameter. These trucks hold 3½ to of coal or 4½ tons of sand or lime; and, lastly, the locomoti built by Messrs. Manning and Wardle is not the property the Festiniog Company, but was made for the branch line fr Duffws to Festiniog village, a distance of about 3½ miles, ope ed a few years since for the carriage of slate by a joint-sto company. This line is worked quite independently of t Festiniog Company.

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BETWE

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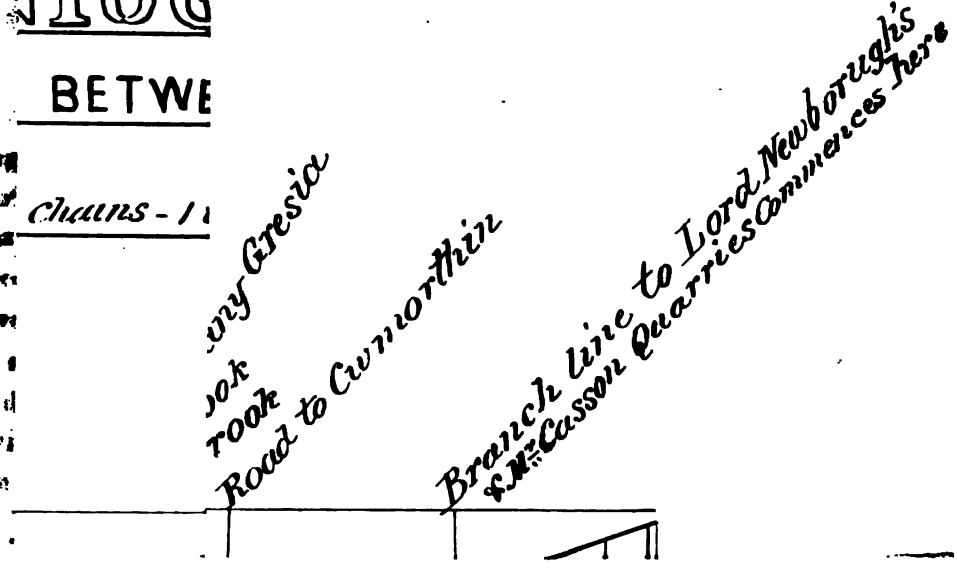

BROELTHAL VALLEY RAILWAY.

(2FT. 7IN. GAUGE.)

(Extract from Engineering, dated 12th March 1869.)

The railway connecting the valley of Bröl with that of Sieg, near Cologne, of which we propose to give some particulars, is of interest to Engineers not only on account of the narrowness of its gauge, which is 2ft. 7in. but also on account of the success with which its working has been attended. The line leaves the Cologne and Giessen Railway at Hannef, and with the exception of a short length near that station it is constructed along the line of the ordinary road, the administrative authorities having permitted a width of about 4ft. 8in. to be taken from the latter for the purposes of the railway.

The Bröelthal valley line was originally designed exclusively for the accommodation of the mineral traffic to the works of Friedrich-Wilhelm-hutte ; but the inhabitants of the surrounding district found it to be to their interest to employ the line for the conveyance of their goods as the cost of transportation was found to be about 66 per cent cheaper than by the ordinary roads ; and as a result the line has at the present time a considerable general goods traffic. The main portion of the line extending from Hennef to Ruppichteroth, is 19·7 kilometres, or about 12¼ miles, in length, and with the exception of about ⅝ mile near Hennef, is constructed as we have already stated along the ordinary road. At a station called Schoneberg a branch 2400 metres or about 1½ miles in length leaves the main line this branch extending to Sanerbach. The Company are also on the point of extending the main line from Ruppichteroth to Waldbröl, a distance of 6¼ miles ; and as this portion of the line cannot be constructed along the ordinary road, the

Prussian Government have granted the company a subvention of 60,000 francs (2400*l.*) in return for which the company have engaged to establish a passenger service over their whole system. The stations on the main line are eight in number namely Hennef, Ollner, Bröl, Ingersauler, Mühle, Herrenstein Schoneberg and Ruppichteroth. Besides these there is Sanerbach, already mentioned as forming the terminal station of the branch from Schoneberg, Hennef, Ingersauler, Mühle, and Schoneberg are good stations, and are also watering stations for the supply of the locomotives ; at Schoneberg, also, are offices and accommodation for the staff. All the buildings are of the simplest kind, and the arrangements for supplying water to the locomotives consist simply of wooden cisterns filled by hand pumps. Hennef, however, has been promoted to the dignity of having an iron tank.

The railway follows exactly the course of the road, and it includes curves of 38 metres (124ft. 8in.) radius, and inclines of 1 in 80. The line is always carried on the most dangerous side of the road, and it occupies a width of 4ft. 8in., the total width of the road being 24ft. 9in. Permission has also been given, in case of a new line being laid down, to increase the width occupied to 6 feet. The upper sides of the rails are on a level with the footpath, and at intervals channels are provided for the escape of the drainage water. Near Hennef, the line, together with the road, passes over the river Sieg on a wooden bridge, which was constructed at the expense of the Company, but of which they keep in repair only that portion traversed by their line, paying for the maintenances of the remainder an insignificant annual sum.

The arrangement of the station at Hennef is this. At this point the Cologne and Giessen line is above the level of

the surrounding soil, and a siding, serves to conduct the larger wagons to the hoppers, into which the minerals are discharged, and from which they are delivered into the wagons of the Bröelthal valley line. At the basement of the range of hoppers are the goods offices. There is also a running shed and turn-table for the locomotives and a weighing machine.

The line is worked by two small tank locomotives, these engines running alternate weeks. These locomotives were constructed at Carlsruhe, and the general arrangement and dimension are as follows :

	ft.	in.
Diameter of cylinders...	0	$10\frac{13}{16}$
Stroke	0	10
Diameter of wheels	2	$3\frac{1}{4}$
Distance between centres of leading and driving wheels	3	$8\frac{1}{8}$
Distance between centres of driving and trailing wheels	2	11
Total wheel base	6	$7\frac{1}{8}$
Diameter of barrel of boiler	2	$9\frac{7}{8}$
Number of tubes 73		
Length...	5	7
Diameter	0	1·38
Length of firegrate	2	4
Width	1	$6\frac{1}{2}$

Heating surface :

	sqr. ft.
Tubes	147
Firebox	27
	174

Area of firegrate ... ... $4\frac{1}{4}$ sqr. ft.

Pressure of steam ... ... 90 lbs. per sqr. in.

Weight of engine in working order. $12\frac{1}{2}$ tons.

The wagons employed on the line are almost all of the following dimensions, &c. :

		ft.	in.
Length of body	... ...	10	2
Width	... ...	4	8
(In the new stock this width will be increased to 5ft. 4in.)			
Mean depth of body about	... ...	5	3
Diameter of the wheels,	2ft. 6¾in. to	3	1
Wheel base	... ... 4ft. 6in. to	5	2
Diameter of axles	... 3in to	0	3½
Weight of empty	... 2½ tons.		
Load carried	... ... 5 ,,		
Total weight loaded	... 7½ ,,		
Weight per wheel	... 1⅞ ,,		
Cost per wagon	... £56 to 92		

The bottoms of the wagons incline from the centre downward towards each side so as to discharge the minerals through side doors. The longitudinal frames of the wagons are of iron of channel sections; and the springs are arranged as usual above the axle boxes, the latter being protected by flaps of leather or canvas, as on ballast wagons, to prevent the dust from the minerals, when the latter are discharged, getting to the bearings. The wagons have central buffers placed above the draw hooks, each buffer rod being connected with the corresponding draw bar by a lever, so that the draw spring serves also as a buffer spring. The draw springs are of india-rubber. Some of the wagons have cast-iron disc wheels without tyres, whilst others have wheels of the ordinary kind with tyres of puddled steel. At first the wagons were run with one wheel of each pair loose on the axle; but the results were not found to be satisfactory, and the plan was therefore abandoned.

The line is laid with rails of the following section. The depth being about $3\frac{1}{8}$in. the width of the top table $1\frac{5}{16}$in. the width of the base $2\frac{5}{8}$in. the thickness of the web $\frac{7}{16}$in. and the weight from 22lbs. to 26lbs. per yard. We cannot speak very highly of this section. The rails vary in length from 14ft. 9in. to 21ft. 8in. and they are carried upon transverse sleepers of oak, 4ft. 2in. long, 6in. wide, and $5\frac{1}{8}$in. deep, placed at a distance apart 2ft. from centre to centre. In the case of the sleepers at the joints the width is increased to 8in. The rails are secured to the sleepers by spikes, and they are connected by fish-plates $12\frac{1}{4}$in. long held by four bolts $\frac{1}{2}$in. in diameter. The gauge of line is, as we have already stated, 2ft. 7in. but on curves of 40 metres (131ft. 3in.) radius the guage is increased to 2ft. $7\frac{1}{2}$in. The super-elevation of the exterior rail on these curves is from $\frac{1}{4}$in. to $\frac{1}{2}$in. A trial was made on the curves of small radius of ordinary flat-footed rails weighing 72lbs. per yard laid without cross sleepers, but the experiment was not successful. Formerly also moveable rails were used instead of the regular points; but now ordinary switches are employed. The crossings are made of hard cast iron. The extension of the line from Ruppichteroth is to be laid with rails weighing 34lbs. per yard, but the distance between the sleepers is to be increased, and they are to be placed at a pitch of 2ft. $11\frac{1}{2}$in. from centre to centre. The rails laid on the main line between Hennef and Ruppichteroth cost 8*l.* 18*s.* per ton, and the fish-plates 12*l.* 12*s.* per ton. About 15 tons of rails and 1000 sleepers are used annually in keeping up the line.

We must now say something concerning the manner in which the line is worked and its commercial results. The usual load drawn by the engines consists of 28 wagons loaded with 5 tons each, giving 140 tons of paying load. The total

weight of the train is thus as follows :

	Tons.
Locomotive	12½
Wagon	70
Load in wagons	140
	222½

It is found that the engines can easily draw 36 loaded wagons, but the above is the usual load. The speed on the level portions of the line is a little over 9 miles per hour; and in traversing those portions of the road at which there are habitations, this speed is decreased to about 5½ miles per hour. In case of meeting a vehicle with horses not accustomed to the passage of the train it is the rule to stop and by means of the brakes, which are in charge of five men the train can be brought to a stand in a distance of about 130 feet.

But one train is run over the line each way per day. This train leaves Hennef at 6 A. M. and arrives at Ruppichteroth at 8·30 A. M. departing from the latter place at 1 P. M. and arriving again at Hennef at 4 P. M. The line is worked with but a small staff. The managing director is M. Gustorff who resides at Cologne, and who is also the managing director of Friedrich-Wilhelm-hutte, while the line is in the special charge of M. Saling, who bears the title of Inspector, and whose head quarters are at Hennef, where a book-keeper is also employed. Another sub-inspector is stationed at Schoneberg, and three men are employed in keeping up the line, one of them receiving 1·875 francs (about 18*d.*) and the two others 1·8 francs (rather less than 15*d.*) per day. The men in charge of the train and their wages are as follows:—

	s.	*d.*	
1 Engine driver	3	1½	per day.
1 Fireman	1	8	,,
1 Guard	2	1	,,
4 Brakesmen each	1	7	,,

There are no signalmen employed on the line.

The merchandise transported is divided into four classes, which are carried at different charges, the goods comprised in the first class being those least liable to injury. The tariff are as follows :—

Class.		Charge per Ton for the entire Distance. s.	d.
1st.	Minerals, limestone, &c. ...	7	0
2nd.	Burnt lime, iron, bricks, &c. ...	8	0
3rd.	Grain and fruits	9	5
4th.	Miscellaneous. (The tariff for this class varies according to the weight).		

The goods belonging to the three first classes are, in addition to the above tariffs, subject to a fixed charge of 4*d.* per ton for loading and unloading. During the year 1864 (the latest year of which we have detailed particulars) the total quantity of goods carried over the line amounted to 32,709 tons, this quantity being divided as follows:

Class.	From Ruppichteroth towards Hennef.	From Hennef towards Ruppichteroth.	Total Tonnage for each Class.
	tons.	tons.	tons.
1st. ...	27,970	2,860	30,835
2nd. ...	344	840	1,184
3rd. ...	140	335	475
4th. ...	50	165	215
	28,509	4,200	32,709

The total receipts for the transport of the above quantities of goods was 2800*l.*; showing an average charge of a little over 1*s.* 8*d.* per ton; while the working expenses during the year, were 1452*l.*, of which 120*l.* was fairly chargeable to the suc-

ceeding year. The difference between receipts and expendi ture available for interest on original cost, &c., was thus 2800 —1332*l.* = 1468*l.* The working expenses were divided a follows:

Charges for management	£150
Traffic charges	188
Cost of traction	428
Station charges	177
Maintenance of way	234
,, rolling stock	216
Miscellaneous	59
	£1452

During the year 1867 the receipts amounted to 2584*l.* and the expenses to 1301*l.*, leaving a balance of 1283*l.* available for dividend, &c. The total cost of the line and rolling stock, &c., has been as follows:

1. Permanent way of main line ...	£9114
2. Bridges over the river Sieg with accessory works	3593
3. Branch line to Sanerbach	1575
4. Stations and Depôts...	3363
5. Locomotive and rolling stock ...	4165
6. General stores	505
	£22,317

The total cost was thus about 1526*l.*, per mile for the to l length of the line. The sum given under the 5th head is divid as follows:

2 Locomotives with spare wheels ...	£1753
29 Wagons without wheels and axles.	1405
101 Axles with wheels	887
Accessories	28
Tools, &c., ...	92
	£4165

The estimated cost of the extension of the line a distan of 6¼ miles to Walbröl, is 9490*l.*

Extract from the Proceedings of the Institution of Civil Engineers.

VOL. 26, PAGE 49.

ON LIGHT RAILWAYS IN NORWAY, INDIA AND QUEENSLAND, BY CHARLES DOUGLAS FOX, M. INST. C. E.

By the term "Light Railways," the Author would wish to be understood such as, either being branches from existing trunk lines, or being intended for districts requiring the development of their traffic, should be constructed in a thoroughly substantial and durable manner, equal in their details as to quality to the best trunk lines, but with every part made only of such strength as to carry loads represented by the rule, that no pair of wheels should be allowed to have more than 6 tons upon it. This would enable these lines to carry the rolling stock of all other railways of similar gauge, with the exception only of the locomotives.

The first railways constructed upon this principle, which have come under the Author's notice, are those of the Norwegian Government; the designs for which were prepared, and the works carried out, under the guidance of Mr. Carl Pihl, the State Engineer. The Author visited these lines in 1864, and was struck with their efficiency and economy. With the exception of the line from Chrstiania to Eidsvold, which was constructed some years since by Mr. G. P. Bidder (Past President Inst. C. E.), and the branches therefrom to the Swedish frontier—both of which are of the 4 feet 8½ inches gauge, that being the gauge adopted in Sweden—the railway system of Norway is upon the light principle, and of the 3 feet 6 inches gauge. The two lines visited by the Author may be taken as types of the system. The first, from Grundset to Hammar on the Miösen Lake, a distance of 24 English miles,

passes through an easy undulating country, has ruling gradients of 1 in 70 with curves of 1,000 feet radius, and has cost, including rolling stock and stations, £3,000 per mile. The second, Throndhjem to Stören, a distance of 30 English miles, passes through a difficult country. The earth works are heavy, including several rock cuttings and embankments of bad clay. There are twelve large bridges on the length of 30 miles, three of them of great height and length, the largest being the Sloppen Bridge over the River Nid. This is 620 feet in length, and has five principal spans of 70 feet each. The piers are 100 feet high, making the total height of the viaduct 110 feet. Up to high-water level the piers are of masonry, to resist the ice, but the rest of the bridge is of timber. The timber trusses are 10 feet in depth, and 11 feet apart, and are constructed upon Warren's principle. These structures are so carefully put together, that there is scarcely any vibration during the highest wind. The gradients on this line are chiefly 1 in 100. There are, however, 5 miles of 1 in 52, and in the opposite direction from the summit, 4 miles of 1 in 42, followed by 4 miles of 1 in 65 and of 1 in 100. Frequent curves are found throughout the line, but especially on the heavy gradients, where they are chiefly reverse curves, ranging from 700 feet to 1,000 feet radius. There are two terminal stations, six intermediate stations, and three stopping places, with workshops and engine and carriage sheds at Throndhjem. The total cost of the line, including rolling stock and station, has been £6,000 per mile.

The permanent way upon these lines consists of flat bottomed rails, weighing from 37lbs. to 40lbs. per lineal yard, fished at every 21 feet, with plates 11 inches long, and secured by dog spikes only to transvers sleepers, 2 feet 6 inches apart from centre to centre ; no fang-bolts, or joint-plates being used.

The sleepers are of pine, 6 feet 6 inches long, by 9 inches by 4½ inches in section, uncreosoted, and half-round, laid the round side up, and adzed, to increase the bearing of the rail, to 5 inches. An inward cant of 1 in 20 is given to the rail. The ballast occupies a space of 8 feet 6 inches wide, and 1 foot 8 inches thick, and is of good quality. The crossings are reversible, and the switches self-acting. The permanent way, after having stood the test of several Norwegian winters, forms a very smooth road. Its repairs employ one man per mile. The general works are thoroughly substantial, the bridges and stations being of pine timber. The lines are 14 feet wide at the formation level.

The locomotives are nearly all alike, with the exception that some have the Bissel bogie, and others Adams' radial axle-boxes. They were constructed partly by Messrs. R. Stephenson and Co., and partly by the Avonside Engine Company. They have outside cylinders, 10 inches in diameter, with a length of stroke of 18 inches, and six wheels—four driving-wheels 3 feet diameter, coupled, and two leading wheels 2 feet in diameter. They are tank engines, and are fitted for burning coal, and have a working pressure of 120lbs. Their weight in working order is 14 tons. The train by which the Author travelled weighed, with the engine, 118 tons, and ran considerable distances at 30 miles an hour, with smoothness and steadiness. The ordinary speed required by the traffic does not, however, exceed 15 miles per hour, including stoppages. In ascending the incline of 1 in 52 an assistant engine was attached, increasing the gross load to 133 tons, or 66½ tons of gross load per engine, which was taken up with ease at about 12 miles to 15 miles per hour. The passenger carriages are 19 feet long, on four wheels, without bogies, and 6 feet 6 inches wide, by 9 feet 9 inches high outside. The goods wagons are 21 feet long, and 6 feet 3 inches

wide. A single central buffer is adopted, forming also the draw bar. The under-frames are of wood.

These lines, which run through thinly-populated districts, already more than pay their expenses, and the results have been so satisfactory, that this system is being rapidly extended.

The railway from the Arconum Junction of the Madras Railway to the town of Conjeveram, 19 miles in length, and of the 3 feet 6 inches gauge, was constructed by Sir Charles Fox (M. Inst. C. E.), and Mr. G. Berkley (M. Inst. C. E.), as Engineers, and by Mr. B. Holloway, as Resident Engineer, for the Indian Tramway Company, Limited. It has now been in operation eighteen months with most satisfactory results.

The line, which runs over a flat country, is formed chiefly of a low embankment, with frequent culverts for drainage, and with two iron bridges, on screw piles, of considerable size, to cross rivers exposed to heavy floods. The works are substantially executed. The permanent way consists of flat-bottomed rails, 35½lbs. to the yard properly fished, and secured by dog spikes to transverse teak sleepers, 2 feet 6 inches apart from centre to centre, and well ballasted. The locomotives and other rolling stock are nearly similar to those used on the Norwegian lines, adopted however to the difference of climate. The cost of this line, which was constructed by the Company's Officers, was £3,200 per mile, including telegraph and stations, or £3,900 per mile including all management and rolling stock. Although the traffic does not require a greater working speed than from 12 miles to 15 miles per hour, the trains have at times been run, with perfect safety, at upwards of 40 miles per hour, including stoppages. During the Festival Days, in May, 1866, twenty-two thousand persons travelled on the line.

The relation of the cost of working to the gross receipts does not exceed that of an ordinary line.

The Government railways of the colony of Queensland—to which Sir Charles Fox, (M. Inst. C. E.), and the Author are the Consulting Engineers—form at present the most extensive system to which this principle has been applied. These lines have been laid out by Mr. A. C. FitzGibbon (M. Inst. C. E.), the Engineer-in-chief to the Colonial Government, who, upon his arrival in the colony, found that the chief want of the country was means of intercommunication, and that it would be better supplied by constructing light, but substantial, railways, than by continuing to spend something like the same amount on roads. Careful surveys were accordingly made, and it was found, that whilst the country both above and below the Main Range of hills was of an easy character, yet to surmount this range, cut up as it is by numerous and deep ravines, would require works of no ordinary character, and such as, for a line with ordinary curves and gradients, would be simply prohibitory in cost. The matter excited much interest in the colony; and the Government having, upon the advice of their Engineer, determined upon adopting a system of light railways, with a gauge of 3 feet 6 inches, much opposition was raised, resulting in the final adoption of the Government plans.

The Southern and Western Railway of Queensland will run from the town of Ipswich to Toowoomba, a distance of 78 miles, and will then divide into two branches, one running to Dalby, a distance of 52 miles, and the other to Warwick, a distance of 62 miles, making a total of 192 miles. About 50 miles have been opened for traffic, and the remaining 142 miles are in course of construction, partly by Messrs. Peto, Brassey, and Betts, and partly by local contractors. A further length of

upwards of 200 miles is under survey. The Little Liverpool incline on this line, which passes a ridge 700 feet in height, is three miles in length, and has ruling gradients of 1 in 50, with curves of 6 chains radius. The main incline which crosses a ridge 1,400 feet high, is 16 miles in length, and has ruling gradients of 1 in 50, with frequent curves of 5 chains radius. The earth works on this portion of the line are very heavy, with cuttings in rock, and eleven tunnels, also in rock, which have been lined with brickwork, and of which one is 27 chains in length. There are also about twenty iron bridges, with lattice girders, 12 feet apart from centre to centre, and in spans varying from 60 feet to 100 feet, with an amount of water-way almost unparalleled on a similar length of line.

One of the chief works is the bridge over the river Bremer close to the Ipswich terminus, for carrying a single line of narrow-gauge railway, and a public road 25 feet wide. It has a width of 37 feet between the parapets, and consists of three spans of 150 feet each. The abutments are of stone. The piers, which are 60 feet high, consist of cast-iron cylinders 6 feet in diameter, sunk into the bed of the river and filled with concrete. Both the main and the cross girders are of lattice construction, the former being 12 feet deep. The top flange is composed of cast iron in a tubular form, the bottom tie of Howard and Ravenhill's rolled links. The cross girders are 6 feet apart from centre to centre, 37 feet long, and 1 foot 9 inches deep. The strains upon the various parts are in all cases within the limits fixed by the Board of Trade, the rolling load being taken at ¾ of a ton per lineal foot of single line. The total weight of the superstructure is only 12 cwt. per lineal foot of the bridge, which is less than one-third the weight of bridges of similar span and width sent out to the colonies for railways of ordinary construction.

The stations on these lines are of an ornamental and somewhat extensive character. The termini at Ipswhich and Toowoomba, several of the roadside stations the engineering workshops, and the engine and carriage sheds, have been sent from England, Messrs. Fisher Brothers having been the contractors for them. They are framed in iron and wood, and covered with zinc, and are fitted with traversers, turntables, cranes, weigh bridges, tanks, and pumping engines, of the same description as those used in England.

The passenger rolling stock is of the best English manufacture. The carriages are generally 32 feet long and 6 feet 6 inches wide, divided into compartments. The first-class carriages have accommodation for thirty passengers, at a cost of £17 17*s*. per passenger; the composite carriages, for thirty-six passengers, at a cost of £12 10*s*. each; and the second-class for forty-eight passengers, at a cost of £8 10*s*. each, there being no third-class. The carriages are mounted upon iron underframes, and are fitted partly with bogie trucks and eight wheels, and partly with Adams' radial axle-boxes and six wheels. The wagon stock varies in length from 14 feet upon four wheels to 20 feet upon six wheels, the latter being fitted with Adams' radial axle-boxes at each end. The bearing, buffing, and draw springs are of the best steel, a matter of importance, as tending towards the reduction of wear and tear. The tires, though originally of iron, are now being gradually superseded by those of steel, of comparatively light section, and fitted with Adams' springs, which have the advantage of allowing slip in passing curves, and of diminishing materially the blow between the wheel and the rail. Everything has been done, in designing this rolling stock, to keep down the weight of the various parts so far as is consistent with strength and durability. The whole of the passenger stock, as well as one-half of the wagon stock,

is fitted with Clark's continuous break, similar to that recommended by Mr. G. Berkley for the Ghât inclines on the Great Indian Peninsula Railway. The cost of this rolling stock per passenger, although fitted with every luxury, shows a considerable saving over that of other railways in sister colonies.

Three classes of locomotives are used on these railways. Tender-engines are employed upon the portions of the line where the curves and gradients are easiest. These engines weigh 15 tons in working order, and are upon six wheels, of which four are 'drivers.' The driving-wheels are 3 feet in diameter, in some cases placed behind, with the leading-wheels 2 feet in diameter, fitted with a Bissel bogie, while in others the driving-wheels are placed in front, and the trailing-wheels are fitted with Adams' radial axle-boxes. The following are some of the leading features of these engines:—Diameter of cylinders, 10 inches; length of stroke, 18 inches; heating surface, 400 superficial feet; length, 19 feet 2 inches; extreme width, 7 feet; wheel base of driving-wheels, 5 feet 6 inches. The tenders are 10 feet long, on four wheels, weigh 7 tons, have 70 cubic feet of fuel space, and tank capacity for 520 gallons of water. These engines are similar to those in use both in Norway and in India, and are found to run smoothly and well up to 40 miles per hour, though their working speed does not exceed 20 miles per hour, at which speed they are capable of taking 90 tons of gross load, including engine, upon a line having ruling gradients of 1 in 100. The cost of one of these engines with tender complete, free on board in England, is £1,400. Tender-engines are also used upon that section of the line which includes the Little Liverpool incline, 3 miles in length; but they are of a more powerful class than the former, weighing 20 tons when in working order, and upon eight wheels. The driving-wheels, six in number, are 3 feet 3 inches in diameter,

placed as closely together as possible, having a wheel base of 7 feet 2 inches only, and the centre pair of wheels being without flanges. The leading-wheels are 2 feet in diameter, and are fitted with a Bissel's bogie. The diameter of the cylinders is 11 inches, the length of stroke 18 inches, the heating surface 600 superficial feet, length 21 feet, and extreme width 7 feet. The tenders are 12 feet long, on four wheels, weigh 9 tons, and have 100 cubic feet of fuel space, and tank capacity for 600 gallons of water. The motion and axles of these engines are of Bessemer steel. These engines, are designed for the same gross load as those of the first-class but for gradients of 1 in 50, though of comparatively short lengths. The cost of one of these engines with tender, free on board in England, is £1,800. The engines for use on the Main Range incline are upon Mr. Fairlie's system. They consist of two bogie frames, carrying a boiler, with a smoke-box at each end, and a central fire-box, having a fire surface 71 square feet. The boiler has two hundred and seventy tubes, is 9 feet 10 inches long, with a total heating surface of 1,000 superficial feet. The frames also form the water-tank, thus keeping the centre of gravity as low as possible. Each engine has two bogies, connected with the boiler by central bogie-pins 3 inches in diameter, and by slotted quadrants having studs working in them at each end of the fire-box. These quadrants form the chief means of transmitting the power of the engine, the bogie-pins being used only as centres upon which the bogies moves. Each bogie-truck is carried upon six wheels, each 3 feet in diameter, having a wheel base of 6 feet 6 inches, the centre pair of wheels being without flanges ; these six wheels are driven by two cylinders, each 11 inches in diameter, with a length of stroke of 18 inches ; making twelve wheels and four cylinders to each engine. The engine is provided with a fire-

door on each side, and the driving platform, which is at the side, is arranged to give the driver a good view when running either way. All the gauges, working handles, reversing gear, and breaks are placed in convenient positions. The weight of the engine, including 150 cubic feet of fuel and 800 gallons of water, is about 30 tons, upon twelve wheels; and the engine is calculated to take 120 tons of gross load, at a speed of 15 miles per hour, up an incline 16 miles in length, having ruling gradients of 1 in 50, and frequent curves of 5 chains radius. The bogie-pins, quadrants, motion, valve-rods, and axles, are of Bessemer steel. The cost of each engine complete, free on board in England, is £2,500, or considerably less than if two tank-engines of half the power had been substituted. The Author has tried several experiments, on the Anglesea Central Railway, with an engine similar in construction, which weighs 24 tons, has eight driving-wheels, and takes a load of 160 tons up 1 in 70, for a distance of 1½ mile, at 20 miles per hour. This engine ran with perfect steadiness at upwards of 40 miles an hour, and the smoothness with which it passed round curve of even 170 feet radius was remarkable.

In designing these several classes of locomotives great care has been taken to keep down the weights, and it will be found that in no case does the weight on any wheel exceed 3 tons. The fire-boxes are made for burning fuel composed of two-thirds of wood and one-third coal; ample heating surface, and fuel and water spaces, being also provided. Break power is applied to nearly all the wheels, and there is an arrangement for sanding the rails under each of the driving wheels. The drivers are well sheltered from the heat. With a view to facilitate passing round curves of sharp radii, and for obtaining elasticity between the rail and the wheel, in none of the engines does the rigid wheel base exceed 7 feet 2 inches; all the

wheels are fitted with the best springs, and with Adams' spring tires, the latter in all cases being cylindrical and not coned.

The permanent way consists of flat-bottomed rails, weighing 40lbs. to the lineal yard, generally in lengths of 20 feet, laid vertically, fished with Adams' bracket plates, secured at the joints by fang bolts, and elsewhere by dog spikes, to transverse rectangular sleepers, laid 2 feet 6 inches apart from centre to centre. The ballast, which is very expensive in Queensland, consists of broken rock. During the manufacture of the rails, a sample was picked out at random from each day's make, and tested upon bearings 3 feet 6 inches apart, with a dead weight of first 15 tons, and secondly 18 tons. The average deflection with the former was $\frac{3}{8}$ths of an inch with a permanent set of $\frac{3}{16}$ths of an inch ; with the latter the deflection was $1\frac{1}{4}$ inch, and the permanent set was $\frac{7}{8}$ths of an inch. The rails were also tested with a weight of 661lbs. falling through 6 feet twice, to show a permanent set of not more than $1\frac{1}{2}$ inch at the second blow, and with the same weight falling through 9 feet once without breaking the rail. The sleepers are cut out in the forest, and at once adzed, to give accurate bearings for the rails, by a machine sent from England, which, accompanied by a portable engine, can run on the railway to the nearest point, and then, having moveable flanges on its wheels, is drawn by horses to the site where the trees are felled. In this way a great saving in haulage and in labour is effected. The cost of the permanent way including ballast of broken stone, is £2,162 per mile, as compared with £2,996 per mile, the cost of the permanent way on the railways of a sister colony.

The cost of these railways taken from Mr. FitzGibbon's estimates is as follows :—

	Total, including Surveys, Land, Superintendence, Stations, Sidings and Rolling Stocks per mile.	Works only. Per mile.
	£	£
Ipswich to foot of Maine Range, omitting Little Liverpool Range	7,732	6,660
Little Liverpool Range ...	12,532	11,400
Main Range	11,132	10,000
Toowoomba to Dalby ...	5,589	4,567
Toowoomba to Warwick ...	5,990	5,445
Actual average cost ...	8,600	...

From this it will be seen, that these lines may be constructed, under the most difficult circumstances, for between £11,000 and £12,000 per mile, and under ordinary circumstances for £6,000 per mile, including everything, and this notwithstanding the rates of labour ruling in the colony ; being from six to seven shillings per day for an unskilled labourer, and from ten to twelve shillings per day for a skilled workmen. It must also be remembered, as remarked by Mr. FitzGibbon, that " the construction of the road and the various appliances employed are in all respects equal to any railway in the world, excepting only that they are limited in power to the wants of the case."*

The Great Northern Railway of Queensland, which will run from Rockhamton in the north several hundred miles into

* Mr. FitzGibbon states, in a note to the Secretary of the Inst. C. E. dated Ipswich, 20th May, 1867, that the line to Toowoomba had then been opened, and that the 16-ton engine, four wheels coupled, took a net load of 40 tons up the Main Range incline at a speed of 12 miles an hour. The cost of the 78 miles, including everything, averaged £13,700 per mile ; while the cost west of the Main Range varied from £6,000 to 7,000 per mile.—Sec. Inst. C. E.

the interior, and which is being carried out under the superintendence of Mr. Henry J. Plews, the Government Engineer for that part of the colony, does not at present call for any special remark. It resembles so far as regards the first section now in course of construction, the lighter portions of the Southern and Western Railway, and is supplied with bridges, permanent way, rolling stock, engine and carriage sheds, and workshops and stations of a similar character. Its locomotives are precisely the same as those of the first-class on the Southern and Western Railway. The passenger carriages, however, which were designed by Mr. Plews, are somewhat different; being 45 feet in length, upon six wheels, fitted with Clark's radial axle-boxes, each holding twenty first-class and forty second-class passengers, the seats being placed longitudinally, on either side of the carriage, with a passage down the middle, and open platforms at the end, from which the breaks are applied. The cost of these carriages is about £10 per passenger.

It so happens that, in the three cases referred to in this Paper, the gauge is 3 feet 6 inches. But the Author considers that the gauge is after all a matter which must be entirely dependent upon surrounding circumstances, and which, if kept within certain limits, will not affect the cost in ordinary countries to nearly so great an extent as that which, the Author would repeat, is in his opinion the basis of the light railway system—the reducing of the weight upon every wheel in the train (including the engine wheels) to 3 tons, the limitation of the speed to 25 miles per hour, and the adaptation of every detail to these conditions. In Queensland, the gauge of 3 feet 6 inches was determined on for the following reasons:—first, there were already two gauges in Australia, so that uniformity was out of the question; secondly, a curve of 5 chains radius on

this gauge is nearly equal to a curve of 8 chains radius on the 4 feet 8½ inches gauge, and the country, on the Main and Little Liverpool ranges, is of so peculiar a character, with frequent ravines and spurs running out from the Main Range, that it was found, by a careful survey and estimate, if curves of 8 chains radius were adopted, as upon the Blue Mountains, New South Wales, the cost would be increased more than three-fold. In the item of viaducts alone, the cost would have been £35,040 per mile, as against £6,100, an amount quite beyond the means of the colony. The gauge was therefore fixed at 3 feet 6 inches, and the minimum radius of the curves was reduced to 5 chains.

In a country, however, where the trunk lies already exist, of either the 4 feet 8½ inches, or some other gauge, and where the country through which the branch line has to pass is not of a peculiarly difficult character, requiring very sharp curves, it would, in the Author's opinion, be generally found advisable to avoid break of gauge, constructing the branch upon the light system, so that it may take all the rolling stock which the parent line may bring to it, with the one exception of the locomotives.

In conclusion, the Author trusts that this paper may elicit a discussion which shall bring forward, more forcibly than he has been able to do, the importance of a system which he believes will be found before long to have much influence upon railway construction for branch lines, both in this and other countries, especially where the amount of traffic is somewhat limited, and where high speeds are not required.

RAILWAYS IN SOUTH AMERICA.

Remarks by Mr. E. Woods, M. Inst. C. E., after the paper read at the Inst. C. E., by Captain Tyler, R. E., on "The Festiniog Railway" (Vol. 24 Page 379, 380.)

Mr. E. Woods thought it was evident, from the observations which had been made, that no one system could be laid down, nor any one gauge be fixed upon, as applicable to all conditions of locality, traffic, &c., but that each district must be treated according to its circumstances. With regard to the Indian gauge of 5 feet 6 inches, he could quite understand, it was most desirable to construct branch lines on the same gauge as the main lines, and in a flat country like India the difference of cost as between a gauge of 5 feet 6 inches and a narrower guage would not be great, the principal item being in the additional length of the cross-sleepers. The rails might be lighter than those of the main line, and the engines for working the branches made light in proportion. Six years ago he had to construct a railway in Chili, 27 miles in length. The line was situated in the lower range of the Andes, where the gradients were necessarily severe and the curves sharp. Here curves of 500 feet radius in combination with gradients varying from 1 in 20 to 1 in 30, constantly occurred. It was said, by the Engineers of the country, that it would be impossible to work that line with locomotives, and accordingly it was laid out for mule traffic, and it was worked by mule power for eighteen months. But owing to the seasons of drought and other causes, the expenses of working were so high, that a decision was come to by the Directors, to work the line by locomotive power. He was called upon to design the engines, and in his design he limited the weight on the driving wheels not to exceed 7½ tons, but the difficulty was to get sufficient

adhesion to take the loads up the severe inclines of 1 in 20 for 7 miles, and of 1 in 30 for 12 miles. That difficulty was overcome by putting 6 driving wheels to the engines, and placing the front end on a bogie truck. The rails, of 42lbs. to the yard, had stood exceedingly well, and up to this time were in good working order, for though the engines weighed 30 tons, the weight, being distributed over so many wheels, had produced no sensible injury to the rails. The ordinary working speed on the inclines was about 12 miles per hour.

From the experience of the working of that line, it was evident that railways of light and inexpensive construction might be advantageously worked, if due regard were paid to the adaptation of suitable rolling stock.

Remarks by Mr. E. Woods, M. Inst. C. E., after the paper read at the Inst. C. E., by Mr. C. D. Fox, M. Inst. C. E., on "Light Railways." (Vol 26 *Page* 67—69).

Mr. Edward Woods thought the Author was right in principle, and it was satisfactory to find, that the system had been worked out on so large a scale, with such economical results. It had been his own lot to adopt the converse of that principle, not so much to originate the construction of light railways as to adapt rolling stock to that class of railways. He had, in fact, for many years past adopted the principle Mr. Fox had enunciated, viz., that of fixing a limit to the weight to be placed upon the driving wheels of the engine, such limit having reference to the light rails in use. The first case Mr. Woods had to deal with was a line of the ordinary English gauge, the Copiapo Extension Railway, originally intended for horse traffic, but for which that mode of propulsion was found to be in-

applicable. He had to design a locomotive to run without injuring the rails, which weighed 42lbs. to the yard. Locomotives of 32 tons weight had worked upon that line for six years, and the road was now in as good order, with regard to the rails, as it was after the first six months' working : but though the engines were of 32 tons weight, the weight was sub-divided, so that not more than from seven to eight tons rested on each pair of wheels. In the case of two other railways in Chili, he had to deal with the rolling stock in the same way. He exhibited a photograph of an engine of a class which he was sending out to that country for the Tongoi Railway, a line of about 40 miles in length, with curves of 187 feet radius, gradients of 1 in 19 for four or five miles, and a gauge of 3 feet 6 inches. The gauge of the other line, the Carrizal Railway, was 4 feet 2 inches, and the same class of engine was working satisfactorily upon it. That engine weighed only 15 tons, with six wheels, each 30 inches diameter, and all coupled, having inside cylinders 12 inches in diameter, with a length of stroke of 17 inches. To adapt it to the sharp curves on the line, the leading and trailing axles were fitted with the translation system of Caillet, which worked very satisfactorily. In the first case named, that of the Copiapo Extension, he had adopted the " bogie" system, but there was in it the disadvantage that the adhesion of the bogie wheels was not available for traction. With regard to the engines of Mr. Fairlie, they were virtually a couple of engines combined. He agreed with Mr. Bruce in preferring two uncombined engines, working together if need be. He thought, where there were steep gradients to deal with, it was not an advantage to have too heavy trains, and such long double engines were inconvenient in the stations, and required large and expensive turntables. They might perhaps be well adapted for special purposes, such as that to which

Mr. Fox had applied them. In working steep inclines like those in Chili, accidents sometimes occurred, the chances of which were diminished when the load was divided, and the evil consequences of a casualty were much lessoned. With reference to the question of the increasing weight of rolling stock, Mr Bruce had remarked upon the engines of twenty-five years ago, which were about the weight of those described in the paper. He remembered the time when, on the Liverpool and Manchester line, an engine of 10 tons was thought a heavy one, and 12 tons very heavy. The rails at that time weighed only 35lbs. to the yard, and with engines of 12 or 14 tons, those rails stood well enough; but as the traffic increased, engines of greater size and weight were introduced, and the consequence was, the rails were soon destroyed, and the line had to be relaid with rails of 50lbs. to the yard ; but the gradual introduction of larger engines rendered those heavier rails useless, and they were replaced by others weighing 60lbs. to the yard. The Grand Junction Railway works were at that time commencing, and Mr. Locke adopted a rail of 62lbs., which was then considered very strong. That answered well with the Grand Junction engines for several years ; but the increased weight of those engines eventually rendered the rails unserviceable, and now the rails weighed 80lbs. to the yard. He thought if the principle advocated by Mr. Fox had been earlier considered and adopted in this country, that to a certain extent much of the cost of altering lines might have been avoided. As an engine of 32 tons was made applicable to 40lb. rails, so he thought engines of sufficient power to meet the demands of a growing traffic might have been devised for the Liverpool and Manchester, Grand Junction, and other lines, which would have allowed the rails to last double the period they did. It not only affected the question of the permanent way, but also

the structures which carried the permanent way. In the year 1844, Mr. Hawkshaw and himself conjointly constructed a viaduct a furlong in length, connecting the Liverpool and Manchester and the Leeds and Manchester railways, at the part which adjoined the Bolton and Manchester line in Salford. That viaduct was constructed of cast-iron columns and girders. Three or four years ago, looking to the greatly-increased weight of the engines of the London and North-Western Railway, they came to the conclusion to call the attention of the Directors to the fact, that as that structure had been designed and executed at a time when the engines were 30 or 40 per cent. lighter than they were now, it might be desirable that it should be looked into, and their joint representations resulted in the strengthening of the whole structure. Similar costly alterations of works had been carried out, and were now going on in other parts of England. He had found, whenever the Government inspectors came to pass a railway, that increased strength of rails and fastenings was demanded. What was admissable a year or two ago was not so now, and this had been the tendency for the last ten or fifteen years, and where it would stop he could not tell; but the subject was one that deserved the greatest consideration of all the members of the profession in order that, if possible, some limit might be assigned to this constantly-increasing expense.*

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* The following additional information has been handed to the Secretary by Mr. Woods :—

TONGOI RAILWAY, CHILI.

Gauge 3 feet 6 inches.

Including extension of 10¼ miles now being made is 41¾ miles in length.

Forms outlet to the rich copper mines of Tamaya. The extension commences at the foot of a range of hills, and to avoid deep ravines it winds much, and has curves of 187 feet radius. There are from twenty-five to thirty curves of small radius. The maximum gradient on the extension is 1 in 19 and there are many steep gradients.

Rails.—42lbs. per yard, in lengths of 18 feet to 20 feet, fish-jointed, flanged, and laid on transverse sleepers of wood.

Wagons.—Platform wagons 7 feet 6 inches by 5 feet 10 inches outside; sides, 13 inches deep, one side falls; wheel centres, 5 feet.

Remarks by Mr. W. Lloyd, M. Inst. C. E. and Mr E. Woods, M. Inst. C. E., after the paper read at the Inst. C. E. by Captain Tyler, R. E., on "Railway Curves and Gradients." (Vol. 26 Page 349—353).

Mr. W. Lloyd had been engaged during the last twelve years in the construction of some of the principal steep inclines in the world. Most of the illustrations and ideas connected with this subject had been derived from Europe alone. His own experience was that many things which were good in Europe frequently caused a great deal of difficulty in foreign countries; and there was one thing in Mr. Fell's engine, admirable as it was, which struck him would cause difficulty in practical operation on a railway abroad—that was the extreme intricacy of the machinery. Simplicity was an essential element in all

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1st Class and 2nd Class Carriages.—16 feet by 6 feet outside; longitudinal seats for twelve passengers.

Engine.—Six-wheeled coupled tank engines. Cylinders (inside) 12 inches by 17 inches; wheels, 30 inches, leading and trailing, fitted with Caillet's translation apparatus; wheel base, 10 feet 9 inches; grate, 2 feet 8 inches by 2 feet 2 inches.

CARRIZAL RAILWAY, CHILI.

Gauge 4 feet 2 inches.

			Feet.
Length of old line	18 miles	Rises	734
Do. extension	4½ „	„	826
	22½ miles	Total rise	1,560

Average gradient over first 18 miles...	1 in 129
Maximum do. over do.	1 in 88
Average gradient over extension	1 in 28
Maximum do. do.	1 in 25

Curves.—373 feet radius and upwards.

Rails.—44lbs. per yard, in 21 feet lengths, fished-flanged.

Sleepers.—Ten to each pair of rails. Dimensions 8 feet × 6½in. × 4in.

Wagons.—Some are on 8 wheels, and weigh 6,000lbs.
Some are on 4 do. do. 2,500 „
100 tons for weight of wagons, represent 63 tons cargo or net load.

Engines.—Six-wheeled coupled tank engines. Cylinders (inside), 12in. × 17in.; wheels, 30in., leading and trailing, fitted with Caillet's translation apparatus; weight in working order, 14½ to 15 tons; tank 500 gallons.

The engines will take a gross load of 125 tons, representing 79 tons of cargo, up the first 18 miles, at an average speed of 9 miles per hour, and they will take a gross load of 52 tons, representing 32 tons of cargo up the 4½ miles extension, at about 5 miles per hour.

things connected with a railway in countries distant from the great centres of industry. He had never doubted that the Alps might be crossed by a railway. The notion was also entertained of going over the Andes, and if that were done the altitude achieved by Mr. Fell and Mr. Brunlees would be greatly surpassed. There would not be the same difficulty with regard to the line itself, but the elevation to be reached was nearly double. It was found in the investigations of the Andes, that there would be no necessity to approach an inclination anything like that of 1 in 12. In the majority of cases a gradient of 1 in 20 or 1 in 25 was the utmost that would be required. The line with which he was principally connected in Chili was the Valparaiso and the Santiago Railway; and he alluded to it more especially because he thought practical results could not be too often referred to. The theoretical features of a scheme might be discussed; but those who were connected, as he had been, with the practical working of railways, as well as with their construction, knew that the results of actual experience afforded the best guide. He had stated in a Paper read before the Institution, that in his opinion it was most essential that engines of the ordinary class and all of the same class should be used on distant railways abroad. Directly two classes of engines on such railways were introduced, the difficulties in the workshops were quadrupled. He knew instances in which an engine of 40 tons had carried a load of 163 tons up 1 in 50 at 10 miles an hour, or four times its own weight on the driving-wheels. The maximum gradient on the Valparaiso line was 1 in 44, and an engine of 37 tons carried 74 tons load up that at 10 miles an hour, or twice its own weight on the wheels. These figures were easily remembered, and he had no doubt the effective duty of the locomotive would be increased by improvements in the machinery. He was delighted

to hear that a load of 40 tons could be taken up an incline of 1 in 12, because many expedients had been tried to get over the difficulty of so steep an ascent.

He would now advert to the Copiapo Extension Railway, from Pabellon to Chanarcillo, for which Mr. E. Woods, M. Inst. C. E., was the consulting Engineer in this country. The summit at Molle was upwards of 4,450 feet above the sea, and Pabellon, where the line commences, was about 2,200 feet above the same level. It had been in operation since February, 1861, and was worked by Messrs. Hawthorn's engines. It was 26 miles in length, and the cost, including equipment, was £6,500 per mile. It consisted of three inclined planes, one rising 2,276 feet in 14½ miles, with an average gradient of 1 in 33, but for short distances of 1 in 26, and 1 in 28 over a portion of the incline. The second was a descending gradient from Molle to Pajonales, 1,990 feet in 9⅙ miles, with an average gradient throughout of 1 in 24. On one portion, however, there was a gradient of 1 in 20, with curves of 720 feet radius, and on other gradients of 1 in 21 and 1 in 24 there were curves of 490 feet radius, in some cases reversed two or three times, and without any intermediate straight line. The last-mentioned inclined plane was an ascending one, with gradients of 1 in 34 and 1 in 25, in the direction that the chief loads were carried, the principal traffic being from the silver mines to the coast. He was sent by the government of Chili to determine the kind of engine that was best adapted for working such lines. The train he took up weighed 57 tons; it went over the gradient of 1 in 20, with curves of 720 feet radius, without difficulty. The retardation by the curves was not more serious than could be overcome by moderating the weight of the train; and there was never any occasion for the weight to exceed 70

tons or 80 tons, as the traffic did not require heavier trains than that. The cost had generally to be regarded in working steep inclines; but in a country like that of which he was speaking it did not enter into the calculation, inasmuch as the price paid for the transmission of goods was so high, that almost any cost would be more than remunerated by the rate of prices charged. The engines had six coupled wheels, 4 feet in diameter; the cylinders were 16 inches in diameter, with a length of stroke of 24 inches; and the fuel burnt was, at the time he spoke of, about an equal quantity of coal and coke. The paying load was two-thirds of the weight of the train. The consumption of fuel was 75½lbs., and of water 66½ gallons, per mile. He considered one-fourth of the weight on the driving wheels was fairly taken up by the engine.

Subsequently a trial was made on another incline in Chili of 1 in 13, over a tunnel under construction, with an engine of the ordinary character of those which were being used in the country at the time; but it was found that the ordinary class of engine could not be utilized for such a gradient as 1 in 12 or 1 in 20. He was, however, reluctant to make special arrangements for a locomotive to work that small portion of the road temporarily; he therefore took a four-wheeled engine off its wheels, placed it as a stationary engine on the top of the tunnel, and worked the incline by a rope. By that means four heavy trains were worked daily; and that during four years, with scarcely any difficulty or accident occurring. Such an instance he thought would afford a useful precedent to Engineers under similar circumstances in foreign countries.

He would now briefly allude to what was proposed on the Mexican Railway, because he had heard some doubts expressed as to what an engine would be likely to do on that line. The proposition was this: The altitude to be reached was 8,400

feet above the sea; and for a distance of 23 miles the average gradient was nearly 1 in 25, with curves of 350 feet radius, and there was one length of 15 miles almost continuously of this gradient. The engine proposed was a double-tank engine, with tender and auxiliary power between. The object of the tender was to carry the necessary supply of water, none being obtainable at the top of the incline. The water from the tender was to be first exhausted, leaving that in the tanks to assist adhesion in the ascent. He calculated that two engines with 21 tons on each pair of driving-wheels, or 42 tons together, ought to take up a train of 100 tons, independently of the weight of the engines; and that would be the maximum load required, inasmuch as the present traffic amounted to only about 80 tons per day. As the rate charged was a shilling per ton per mile, the money value of a train of 100 tons for 15 miles would be £75, so there was little need to take into consideration the cost of working such inclines under similar circumstances.

Mr. E. Woods could corroborate what had been said with regard to adhesion under favourable circumstances; and it was confirmed by the results of Mr. Lloyd's practice in Chili, Table No. 1, page 70, showed the actual work done on the railway of which Mr. Lloyd had given a description, and which had now been worked by locomotive power for six years. He had stated on a former occasion, that this line was not originally designed for locomotives, but was intended to be worked by animal power. It was so worked for two or three years. but the expense caused it to be abandoned, and locomotives were substituted. The lightness of the rails (42lbs. to the yard) compelled him to design engines in which the weight on the driving-wheels should not be greater than those rails would stand, and the engine he had designed (Table No. 2, p. 70)

had outside cylinders, six coupled wheels, 4 feet in diameter, with a four-wheeled bogie in front, to pass round curves of 500 feet radius. The weight of the engine, in working order, was 32 tons, and that of the tender 25 tons : on the driving-wheels it was 24 tons. A comparison of that with the work of the engine given in Table No. 3, p. 71, showed that the coefficient of adhesion was as nearly as possible one-fourth of the driving weight. The climate of Chili was, however, peculiarly favourable for working steep gradients. There was very little rain at any time, and the rails were almost always in good order. The line had been worked four or five years entirely without accident, until about half a year ago, when one occurred owing to the breaks not acting. Mr. Lloyd had correctly stated that the Chief loads were from the mines to the coast. They were carried on a gradient averaging 1 in 23, or 1 in 24, up to Molle, before they could be sent on to Pabellon ; thence they were carried along the Copiapo Railway (extending for a distance of 60 miles) to the coast. The load had on one occasion been 77 tons, exclusive of the engine and tender, making a total of 134 tons. Under ordinary circumstances, the weight of the load was not more than 50 tons, the total being 107 tons. The Tables which he had prepared, independently of Mr. Lloyd's observations, and without communication with him, were confirmed by that gentleman's personal experiments on the line. The speed was necessarily limited in descending: the rule was that the trains should not descend at a greater speed than 12 miles an hour ; but that was sometimes a little exceeded. The average speed up and down was about 13 miles an hour. A question had been asked as to the relative amount of coke and coal used for fuel in working these trains. The proportion of coal was greatest. In the first instance coke alone was burnt ; then coke and coal mixed together ; and now coal was almost

exclusively used. He thought a well-proportioned 'all occu pied' engine could take itself up an incline of 1 in 4 with it own wheels, if the rails were clean and in good order.

COPIAPO EXTENSION RAILWAY 1860.

TABLE 1.

Particulars of Engines.

Outside cylinders.	Six coupled wheels, 4 feet diameter.
Four-wheeled bogie.	Cylinders 16 ins. diam., and 24 ins. stroke.
Weight of engine in working order	32 tons.
Ditto tender " "	25 "
Total	57

TABLE 2.

LOADS taken over the line, gradients averaging 1 in 23 and 1 in 30.

Heaviest train ever taken over the line:—

Engine	32 tons.	
Tender	25 "	
		57 tons.
Gross load of wagons and carriages ...		77 "
Total weight ...		134 tons.

Ordinary trains:—

Engine	32 tons.	
Tender	25 "	
		57 tons.
Mineral trucks	Tare 11 tons.	
Minerals, &c.	Nett 26 "	
	37 "	
Passenger carriages, with passengers	13 "	
		50 "
Total		107 tons.

Mean speed of train, 13½ miles per hour.

Heating surface:—

Fire-box	75 square feet.
Tubes	926 "
Total	1001 "

Area of grate 14¼ square feet, or 1-70th of heating surface.

TABLE 3.

Greatest load taken up gradient of 1 in 23 = 134 tons.

Gravity	97lbs.	per ton.
+ friction	12 ,,	,,
Total	109 ,,	,,

Traction = 134 tons × 109lbs. = 14,606lbs.

24 tons (= 53,760lbs.) on driving-wheels.

Coefficient of adhesion = $\frac{14606}{53760} = \frac{1}{3{\cdot}7} = 0{\cdot}27$

Ordinary load taken up, 1 in 23 = 107 tons.

Traction = 107 tons × 109 lbs. = 11,663lbs.

Coefficient of adhesion = $\frac{11663}{53760} = \frac{1}{4{\cdot}6} = 0{\cdot}22$.

In the 1st case,

14,606lbs. traction corresponded to a mean pressure in the cylinder of 114lbs. per square inch.

In the 2nd case,

11,663lbs. traction corresponded to a mean pressure of 91lbs. per square inch.

Extract from a paper read before the Institution of Civil Engineers by W. Lloyd, M. Inst. C. E. being a "Description of Santiago and Valparaiso Railway Chili; with remarks upon Resistances from Curves on Railways and upon Coal Burning Locomotives." (Vol. 23 Page 382—398.)

GENERAL DESCRIPTION OF THE LINE.

The railway, for the first 3 miles from the Valparaiso station, passes along the coast of the Pacific, crossing its various indentations, or cutting through the projections of the granite cliffs. This portion is level throughout, and is about 12 feet above highwater mark. The line, however, is a series of curves of small radius, there being five of 660 feet, one of 750 feet, one of 800 feet, one of 818 feet, four of 900 feet, and three of 1,000 feet. All the exposed parts of this portion of the line are defended against the violence of the winter gales by massive sea walls, constructed of heavy granite blocks, laid dry, at an angle of 2 to 1, and upon these rest a parapet of masonry. The sea walls are protected in front by a foreshore,

30 feet in width of heavy loose stone, and although on several occasions severely tried, have hitherto resisted perfectly the shocks of the seas which occasionally roll in with extraordinary violence. At two points, where sea walls would have been difficult of construction, the line is carried upon timber bearings, through which the seas pass ; one of these being 300 feet in length, upon a curve 660 feet radius. Upon this coast portion there are nine cuttings from 40 feet to 60 feet in depth, and one tunnel, 420 feet in length (the first railway tunnel executed in South America), all through syenitic rock, upon which lie beds of recent marine shells. It is reported, that the whole of this part of the coast, during an earthquake in 1822 was permanently upheaved to the extent of several feet. The beds of shells are, however, of much more ancient date, being met with at an altitude of more than 1,000 feet above the sea ; and the upheaval, if such ocurred, must have been remarkably uniform, as there remains no evidence of such recent volcanic action.

At the third mile from Valparaiso, the line diverges from the coast, and, passing through a cutting of more than 60 feet in depth, proceeds along the valley of Vina del Mar for 5 miles. Upon this portion the curves are generally good, and the gradients never exceed 1 in 100 ; the works also are of minor importance, but walls were required, in places, as a protection against the floods of the Quillota river, which, although dry in summer, is frequently 800 feet wide and ten feet deep in winter. The course of this river is crossed by a wrought-iron plate-girder bridges of six 50 feet spans, which was the first bridge upon this principle erected upon this coast, and the line leaves the Vina del Mar Valley, and follows upward the course of the Quilpué river. In the two succeeding miles serious difficulties were encountered, commencing with a rock-cutting, 90 feet in

depth, followed by a long embankment, 30 feet in height, and a second cutting, 40 feet in depth; immediately after which, in the next half mile, are four viaducts, each above 60 feet high, crossing the Quilpué river, which here flows with a tortuous course, down a deep ravine, with precipitous sides, about 600 feet in height. Two of these viaducts have spans of 110 feet, a third has two spans of 90 feet each, and the fourth has six spans of 66 feet each, the aggregate length of the four viaducts being 1,350 feet. These works were at the time of their construction by for the largest of the kind yet erected upon the coast of the Pacific, and are now only exceeded by the Maquis Viaduct, yet to be described. All these viaducts are upon a gradient of 1 in 50, and upon one of them commences a curves of 600 feet radius.

Beyond the fourth viaduct the valley becomes more contracted, and involved a succession of cuttings from 30 feet to 40 feet in depth, through a quartoze rock containing gold, which is here obtained by washing; and at one place, a fifth viaduct over the same river was requisite, of two spans of 60 feet each and 25 feet in height. A short distance beyond this bridge the gradient of 1 in 50 terminates, and the line now ascends the Quilpué Valley as far as the eighteenth mile from Valparaiso, with gradients in no case exceeding 1 in 90. Upon this part the curves are not less than 1,000 feet in radius, nor are the works of serious importance. But at the eighteenth mile the summit of Lebu is attained, and here there is a cutting, partly in rock, ¾ths of a mile in length, with a maximum depth of 40 feet. From this summit, which is 510 feet above the Pacific, the line descends for the next 2½ miles at the rate of 1 in 65; but the curves are moderate and the works are light: this gradient is succeeded by others of 1 in 90, as far as the twenty-fourth mile, at the Limache River, and upon this latter

portion the principal works are a cutting 40 feet deep, $\frac{1}{3}$rd of a mile in length, and a timber viaduct of ten 24-feet spans, 25 feet in height.

The crossing of the Limache River, which in winter is a formidable stream, is accomplished by three bridges, together 500 feet in length, one of which is of wrought iron, and the others are of timber. The level of this part of the line is 215 feet above the sea. From this point the line again ascends by a gradient of 1 in 90, nearly 3 miles in length, upon which is a curve $\frac{1}{2}$ a mile long with a radius of 1,000 feet; and at the twenty-seventh mile from Valparaiso the second summit of San Pedro is reached, the level of which is 384 feet above the sea.

At this point the line passes through a spur of the Andes, by a tunnel 1,600 feet in length, approached on each side by rock excavations, each $\frac{1}{3}$rd of a mile in length, and of the maximum depth of 60 feet. This tunnel, the chief one upon the line, passes for $\frac{2}{3}$rds of its length through granite and trap-rock, containing much water, the remaining third being through decomposed rock and clay. It was considered necessary to arch it throughout, and the novelty of such constructions in that country, the nature of the material perforated, and various legal difficulties connected with it, delayed its completion for so long a period, that it was deemed advisable to form a provisional line over the summit, by which the traffic was opened to Quillota four years sooner than it otherwise would have been. This provisional line was worked by one of the ordinary passenger locomotives employed as a stationary engine, and by its means 250 passengers and 100 tons of goods were daily conveyed over the crest of the hill; up-inclines of 1 in 13 and 1 in 15 on each side, and over an altitude of 150 feet above the starting point, without the slightest accident during the whole period above mentioned.

This tunnel presented another peculiarity in the successful stoppage of a slip which took place at one point. This slip was occasioned by the decay of the timbering under the wet decomposed rock during the suspension of the works. When the works were resumed, the material descended into the tunnel as fast as it could be removed, in spite of every attempt to restrain it, until the surface of the ground, 120 feet over the tunnel, began to sink. The settlement above looked very alarming ; but as it was considerably larger in diameter, than the orifice could possibly be below, the following plan was adopted and almost immediately took effect. The surface of the ground was allowed to settle about 10 feet, and a large frame of timber was constructed fitting the aperture, the timbers crossing one another like lattice work, and being strongly bolted together. Upon this lattice frame brushwood was laid thickly, and the excavation below was then proceeded with. The frame rapidly disappeared, the sides of the cavity above the tunnel falling in as it descended ; a short time was allowed to elapse, when a second frame of similar construction was again inserted above, and this was likewise covered with brushwood. Almost immediately after the insertion of the second frame, the miners below began to gain upon the slip, and at length were enabled properly to insert the timbering. It was discovered in doing so, however, that the first frame had descended to the tunnel, and had perfectly plugged up the aperture. This may not have been the first occasion that this plan has been tried, but it is mentioned as a successful instance of the stoppage of a slip, which, probably, could not have been arrested by any other means.

Beyond the San Pedro Tunnel, which is upon a gradient of 1 in 90, and partly curved, the line a second time descends into the Valley of Quillota, by gradients of 1 in 90 and 1 in

253, as far as the San Pedro River, which is crossed at the thirtieth mile. On this descent there are some rather heavy earthworks ; but after passing the river, the country becomes favourable, and a straight line of 4 miles, ascending at the rate of 1 in 172, extends to Quillota, an agricultural town of about 10,000 inhabitants, situated on the bank of the Aconcagua River, at a distance of 34 miles from Valparaiso.

The railway passes through one of the streets of this town; and, after leaving it, ascends the Valley of the Aconcagua for 20 miles, upon the first seven of which no difficulty of any importance was encountered. At the forty-first mile from Valparaiso, however, the line approaches the river, the course of which it follows for the next 13 miles, skirting as closely as possible the bases of the abrupt hills which form its southern bank ; and, at places, the line is forced into such close contiguity with the stream, that extensive walls of loose stone have been rendered necessary for protection. The Aconcagua is one of the principal rivers of Chili. It rises in the main Cordillera, and takes its name from an extinct volcano, which is believed to be the loftiest peak of the Andes, rising to an altitude of about 23,000 feet. It is not navigable in any part, and having, almost throughout, a fall of forty feet to the mile, its current is extremely rapid ; and during rain-storms, and also in the summer season, when the snows are melting, the body of water flowing along it is very imposing, although at other times insignificant in volume.

With the exception of the protective walls, in the construction of which a large quantity of rock from the hill slopes in the vicinity was used, the remaining works have no claim to any particular notice ; but in passing round some of the spurs of the hills, a few curves of 600 feet radius became indispensable ; these all occur on moderate gradients, and the principal portion of this

extent of line is straight, ascending at the same rate as the valley itself.

At the fifty-fourth mile from Valparaiso, the line diverges from the bank of the Aconcagua River, and ascends the Valley of Tabon, crossing the Vichiculen River, by a skew plate-iron bridge of three 50 feet spans, at an angle of 29° ; upon the first 3 miles in this valley the line is straight and the gradient moderate, until the Station of Llaillay is reached, at which point the Tabon Incline commences.

The Tabon Incline.

The entire length of this incline is 63,347, feet, or nearly 12 miles. Its altitude at the commencement is 1,280 feet, and its summit is 2,640 feet above the sea. It therefore rises 1,360 feet, or at the average rate throughout of 1 in 46½. It commences with a gradient of 1 in 100, for 1,700 feet in length, which is, for the most part, upon a curve of 1,495 feet radius ; the ascent for the next 1,800 feet is increased to 1 in 48, on which gradient there is a continuous curve of 1,719 feet radius. The incline now continues with a diminished ascent of 1 in 68 for a length of 2,800 feet; here occurs the first curve of the minimum radius of 604 feet, and at the termination of this gradient, and upon the same curve, the maximum acclivity of 1 in 44½ commences. This maximum gradient of 1 in 44½, or 120 feet per mile, extends over the succeeding 3½ miles, and upon it occur sixteen curves of 604 feet, one curve of 633 feet, and one of 702 feet radius ; the aggregate length of the curves combined with this gradient amounting to more than 1½ mile.

It is upon this incline that the principal difficulties of construction were met with. The Valley of Tabon terminates in a gorge, with perpendicular cliffs on both sides ; through this gorge flows a small mountain stream, the bed of which descends

with such rapidity, that the line to attain the upper part of the gorge, has been so carried long the abrupt and rugged sides of the mountains, as gradually to arrive at the required altitude. The railway, therefore, runs along the face of the mountain about 300 feet above the valley, and the rocky cliffs, in places, beetle over at an altitude of nearly 1,000 feet.

The works on this portion of the line consists of two tunnels through porphyry, respectively 500 feet and 350 feet in length; several heavy retaining walls, one 40 feet in height; a number of embankments from 30 feet to 80 feet in depth, and a succession of deep rock excavations. At one point, the line, for one half its width, is in a cutting 70 feet deep, while the remaining half is formed of embankment, the slope of which extends down the hill side to about 250 feet below the rails. It was of course indispensable that the seats of all such embankments should be 'benched.' In addition to the ordinary excavations, a large number of loose rocks upon the hill sides required removal, lest the movement of earthquakes should cause them to descend, as on more than one occasion during the progress of the works similar rocks had been observed to do. In the execution of this part of the line, about 3,000 men, chiefly miners, were employed for two years; and a large quantity of gunpowder was used blasts of 10 cwt. or 20 cwt. of powder being frequently employed.

Succeeding the gradient of 1 in 44½ just described, is a gradient of 1 in 46 for ½ a mile, the greater part being upon curves of 604 feet radius, and upon this gradient and curve are some heavy rock cuttings, in addition to the Maquis Viaduct.

The Maquis Viaduct is the principal work of its kind yet erected upon this coast. Its altitude in the centre is 126 feet, and its total length is about 200 yards. It has one span of 148 feet, and four spans of 100 feet, the former being tubular,

the others formed of plate-iron girders. The piers consist of cast-iron columns, braced with wrought iron, and resting upon masonry. The arrangement of the columns is somewhat novel, and the upper part of the piers is formed of a boiler-plate entablature, which has a good appearance, and affords great stiffness to the piers. The whole of the ironwork for this viaduct was obtained in England, Messrs. Kennard suplying the piers, and the 'Canada Works' the tube and girders. The best evidence of the excellence of its manufacture, is that the whole was erected in three months. The total weight of iron in this structure is about 750 tons, and the total cost of the viaduct, erected, amounted to about £40,000 or £66 per lineal foot.

The line, after passing this viaduct, immediately enters another tunnel, 350 feet in length and the gradient again ascends at the rate of 1 in 44½ for a distance of rather more than a mile; the curvature, however, is less abrupt, the radii of the sharpest curves being respectively 718 feet and 955 feet. The works upon this length are still heavy, consisting of deep side-long rock excavations and embankments, with three plate-iron bridges over the Tabon River. Beyond this portion, a gradient of 1 in 46 extends for 3,800 feet. About one-third of this part of the line is straight; the remainder consists of curves varying from 800 feet to 1 mile in radius.

The incline now ascends, at the rate of 1 in 45, for 2 miles, the greater part of which is straight, and then is continued for 1,800 feet by a gradient of 1 in 50, on which are two curves of 662 feet and 717 feet radius respectively; and from the extremity of this gradient to the summit of Montenegro, a distance of 3 miles, the ascent is uniformly at the rate of 1 in 45; the curvature upon the latter being more moderate, most of the curves exceeding 1,400 feet in radius, and none being of less radius than 819 feet.

Upon the latter 5 miles of the incline, the works, excepting the summit cutting, which is 1½ mile in length, and on an average 30 feet deep, are not of an arduous description; but the material is, more or less, the same throughout, a tough porphyry conglomerate, exceedingly troublesome to blast.

Out of the total length of 12 miles of the Tabon Incline, $6\frac{1}{10}$ miles are curved, and upon all the curves of less than 1,000 feet radius, it has been deemed prudent to lay a guard rail on the inner side of the curve. The permanent way is formed of fishjointed T rails 84lbs. to the yard, fastened to sleepers of two kinds of native timber, a species of cedar called 'Alerce,' and a cypress. The distance from centre to centre of the sleepers is 3 feet, the rails being fastened to them by wrought-iron spikes, weighing half a pound each.

The descent towards Santiago from the summit is effected for the first 3½ miles, with an inclination of about 1 in 80, the curvature being favourable, and the works light; a short interval occurring upon this distance of 1 in 300, for the establishment of the summit station. To this gradient succeeds one of 1 in 183, for 2 miles in length; upon this distance, and indeed as far as the seventy-eighth mile from Valparaiso, the alignment is altogether favourable.

At this point, however, commences the third principal difficulty—the passage through an exceedingly deep and tortuous ravine 4 miles in length called 'San Ramon.' Upon this portion, there are three iron bridges over the River Lampa, and a continued succession of heavy earthworks, and extensive river walls, the aggregate length of these bridges is 800 feet, one being 40 feet in height, the two others are not more than 20 feet high, but both are askew, with angles of 30°. Two of the excavations approach 100 feet in depth, both in syenitic rock, similar to that encountered near Valparaiso, and many of

the other cuttings reach the depth of 50 feet. The gradients upon this portion are respectively 1 in 55, 1 in 60, 1 in 71, 1 in 75, and 1 in 100, and upon the maximum gradient of 1 in 55, there are reversed curves of 600 feet and of 700 feet radii, extending throughout its entire length, for about one mile.

Beyond the ravine of San Ramon, which terminates at the eighty-second mile from Valparaiso, the country becomes more open, and the line is enabled to pursue a more direct course. Nevertheless, in passing the village of Tiltil, and in approaching Polpaico, the rapid declivity of the valley necessitated the introduction, in one or two cases of gradients of 1 in 67 and 1 in 72; the works at this part are exceedingly light, and the material consists chiefly of gravel.

At Lampa, where there is a station, the line again crosses the river of that name, by an iron bridge of eight spans of 50 feet each, and thence, as far as the ninety-third mile, there are no works of importance, except a bridge of two 66-feet spans over the Chacabuco River.

Just beyond the ninety-third mile from Valparaiso, the line leaves the valley of the Lampa, and traversing a low range of hills with a cutting about 30 feet deep in shale, descends for the extent of one mile at the rate of 1 in 52, into the valley of Santiago, near the Batuco Lake, which is crossed at the ninety-sixth mile. The lake is at this point nearly a mile in width after rains, but is of little depth; the line is carried across it by an embankment having its slopes protected against the wash of the water by loose stone. From the embankment to the one hundred and eighth mile, the line is throughout straight, and practically level; nor in the remaining six miles to Santiago was any particular difficulty encountered, except in passing two points at Renca, of basaltic rock, and in crossing the Mapocho River by a bridge at the entrance to the capital. The bridge

consists of three spans of 100 feet each, supported upon cast-iron cylinders 6 feet in diameter, let into the bed of the river to the depth of 23 feet, and afterwards filled with concrete. This system of foundations, employed in this case for the first time on the coast, has been universally admitted to be the best adapted, and most economical for bridging the rivers in Chile, on account of their rapid currents and frequent liability to floods.

The termination of the Santiago and Valparaiso Railway in the capital, is at an extensive station, serving also for the 'Southern Railway of Chile', a line now in operation for 84 miles through the most fertile provinces of the country, and which it is proposed to extend ultimately as far as the frontier of Araucania.

This detailed description of the principal features of a Chilian railway, may, it is believed, be of interest, to those who are called upon to exercise their profession in countries such as that under notice ; and the Author entertains more confidence in this respect, because descriptions of similar cases, recorded in the Minutes of the Proceedings of the Institution, have afforded him previously much valuable data. Nor can he forget, that it was chiefly through the advice and council of the late Robert Stephenson, and by the encouragement of other friends connected with the Institution that he has been enabled to carry out successfully a laborious and difficult task.

Particular stress has been laid upon the combination of steep gradients with abrupt curves, because in countries like Chile, railway communications cannot be effected without them, and any practical data respecting them cannot fail to be of value. In the published account of the Bhore Ghât, the Semmering, and other principal inclines, this information is not given with sufficient distinctness, to afford accurate con-

clusions, as to the positive impediments offered to the traffic of those lines ; therefore, appended to the Paper is a list,* containing the lengths of every curve and straight line upon the Tabon Incline, specifying the gradient upon each.

The subject of the resistance due to such combinations, is of the utmost importance, and will probably bear much more investigation than has hitherto been devoted to it. American Engineers, such as Latrobe, who have had great experience upon this point, appear to underrate the effect which curvature produces in retarding the passage of trains. English authorities differ materially in their views upon the matter, and a recent writer gives two formulæ for arriving at an estimation of this resistance, which are perfectly opposed to one another, so that reliable data seem yet to be wanting. A few imperfect experiments made by the Author, upon the Paso Hondo Incline of 1 in 50, with curves of 600 feet radius, and upon the level line nearer Valparaiso, with similar curves, although not presented as more than mere approximations, to the truth, may at least afford matter for discussion.

The experiments were made with a dynamometer, constructed in Chile for the purpose, similar to a spring-balance in its form and arrangement ; but of only sufficient power to enable the experiment to be made with one loaded wagon, an ordinary four-wheeled open goods wagons, having wheels 7 feet apart, and weighing when empty 8,200lbs. For the purpose of this experiment it was loaded with pig-iron, until the gross weight amounted exactly to 10 tons. It was then drawn at a slow rate by a locomotive, so as to enable the observers to note the effect. The observations were taken upon a calm day.

* This list may be consulted at the Institution.

Resistances to Railway Trains, in lbs. per Ton of Train.
On Straight Lines, Level, and Inclined.

If Curved or Straight.	Gradient.	Friction, Concussion, &c.	Gravity.	Resistance from Curvature.	Total of Resistances.	Observations.
		lbs.	lbs.	lbs.	lbs.	
Straight.	Level	10	...	...	10	Satisfactory.
"	1 in 500	10	2½	...	12½	Moderately good.
"	1 in 875	10	5	...	15	
"	1 in 250	10	5	...	15	Imperfect.
"	1 in 200	10	10	...	20	Satisfactory.
"	1 in 180	10	10	...	20	Fair.
"	1 in 114	10	20	..	30	
"	1 in 111	10	25	...	35	
"	1 in 100	10	20	...	30	Satisfactory.
"	1 in 50	10	40 to 45	...	50 to 55	
On Level Lines and Curved.						
Radius. feet.						
660	Level.	10	...	15	25	
880	"	10	...	7½	17½	
900	"	10	...	10	20	
1000	"	10	...	10	20	
1300	"	10	...	7½	17½	
1 mile	"	10	...	2½	12½	
On Inclines and Curves combined.						
Radius. feet.						
600	1 in 50	10	45	15	70	
1000	1 in 50	10	45	10	65	
1500	1 in 50	10	45	5	60	
600	1 in 100	10	20	15	45	
1000	1 in 100	10	20	10	40	
800	1 in 100	10	20	10	40	
1500	1 in 100	10	20	5	35	
3000	1 in 100	10	20	5	35	
2000	1 in 200	10	10	5	25	
5280	1 in 875	10	2½	2½	15	

It will be noticed that some of these results are slightly contradictory; but the approximations to the ever-varying indications of the dynamometer, as observed by two persons, are the closest that could be made. According to such experiments, it is apparent, that upon a straight line, with a gradient of 1 in 50, the resistances correspond with those afforded by the ordinary mode of calculation, viz., about 55lbs., per ton of train; while upon the same gradient, combined with curves of 600

feet radius, the resistances were augmented to 70lbs, per ton of train; showing that the additional resistance, due to the curvature, amounted to 15lbs. per ton of train. By the formula of Latrobe, the resistance due to a curve of 600 feet radius, would amount only to about one-third of the above result, viz. 5·09lbs. per ton of train; while Professor Rankine (in his "Civil Engineering," 1862, p. 648) approaches much closer to the results of these experiments, as his calculation would give 12·3lbs. per ton of load, which seems to be much nearer the truth.

These experiments would appear to show that, upon a curve of 1,000 feet radius, the resistance is double that upon a straight line, and that the resistance produced by a curve of 600 feet radius is equal to the gravity on an inclined plane of 1 in 150.

Approximately, the resistance due to curvature may be found by either of the two following rules:—Divide the number of lbs. in a ton by 0·224 of the radius of the curve; or, multiply the deflection angle of the curve by 1·75 to give the resistance in lbs. per ton of train due to curvature.

It should be remarked, however, that the gauge of the line on which these experiments were made, is 5 feet 6 inches, and that the proper super-elevation of the outer rail had been given to the curve.

The plant employed upon the Santiago and Valparaiso Railway is upon the European system, the engines and most of the other rolling stock having been obtained from England. The engines are at present of two classes, ordinary six-wheeled passenger and good engines, four wheels being coupled; but special engines have been ordered for the Tabon Incline.

The dimensions of the engines now in use are as follows:—

	Passenger Engines.	Goods Engines.
Length of fire bars	3 ft. 6 ins.	3 ft. 6 ins.
Width of ditto	3 ft. 9 ins.	3 ft. 9 ins.
Surface of ditto	13·12 sq. ft.	13·12 sq. ft.
Number of Tubes	161	193
Length of ditto	11 ft. 6 ins.	11 ft. 6 ins.
Inside diameter of ditto	1¾ ins.	1¾ ins.
Fire-surface of ditto	848 sq. feet.	1,016 sq. ft.
Heating surface of fire-box	74 sq. ft.	78 sq. ft.
Total fire-surface...	922	1,094 sq. ft.
Inside diameter of boiler...	4 ft. 2 ins.	4 ft. 2 ins.
Quantity of water in ditto	730 gals.	730 gals.
Pressure of steam in boiler	110 lbs.	120lbs. per sq. in.
Steam cut off in cylinder	17, 15, 13, 10½, 8¼, 6, 3, ins.	17, 15, 13, 10½, 8¼, 6, 3, ins.
Diameter of cylinder	15 ins.	16½ ins.
Length of ditto	26 ins.	28 ins.
Stroke of piston	22 ins.	24 ins.
Diameters of leading and driving wheels	5 ft.	4 ft. 6 ins.
Ditto of trailing ditto	3 ft.	3 ft.
Gauge of rails	5 ft. 6 ins.	5 ft. 6 ins.
Centres of wheels, leading to driving	8 ft.	8 ft.
Ditto, driving to trailing...	5 ft. 6 ins.	5 ft. 6 ins.
Extreme centres	13 ft. 6 ins.	13 ft. 6 ins.
Width of tires	5 ins.	5 ins.
Incline of tires	1 in 6	1 in 6
Weight on leading wheels	20,065 lbs.	24,000 lbs.
Ditto on driving ditto...	24,000 lbs.	26,000 lbs.
Ditto on trailing ditto...	9,016 lbs.	9,016 lbs.
Ditto, Engine empty	53,081 lbs.	59,016 lbs.
Ditto, tender ditto	18,600 lbs.	18,600 lbs.
Water in tender	1,000 gals.	1,000 gals.
Fuel in tender	2,000 lbs.	2,000 lbs.

The fuel employed is exclusively native coal, from the mines of Lota, a port about 300 miles south of Valparaiso. The engines were originally intended to burn coke, but Mr. Mather, the Locomotive Superintendent of the line, at a trifling expense, not exceeding £5 each, has, by skilful adaptation, fitted them for using coal, and effected an economy in the cost and consumption of fuel of about 30 per cent. The alterations consisted in placing in the fire-box a firebrick bridge in front of the tube-plate, just below the level of the tubes; underneath this were introduced two hollow stays in the front of the fire-box, to admit air. A deflecting-plate was likewise added for the fire-door, which is made to ship, or unship at pleasure;

and an annular steam-jet was introduced within the chimney, the exhaust-pipe being cut down, at the same time, to a level of 1 inch above the top row of tubes, leaving its diameter 5 inches. In addition to these alterations, the fire-bars were lowered 5 inches (leaving them 28 inches below the tubes), and were brought much closer together. The effect of the alterations has been most satisfactory. Formerly the fuel employed was one-quarter English coke, at 16 dollars per ton, and three-quarters Chile coal, at 9 dollars per ton; and the average consumption per mile, with light train, was 9·41lbs. coke, and 26·15lbs. coal = 35·56lbs. fuel per mile; and the expense per mile was 17 cents, or 8½*d.* The consumption at present, of coal only, is 35·80lbs. per mile for goods engines, and 22·86lbs. per mile for passengers engine, or an average of 29·83lbs. per mile of fuel; and the cost of coal in Valparaiso being taken at 9 dollars per Chile ton of 2,200lbs., as before, the expense per mile run is, for passengers engines, 9 cents, or 4½*d.*, and for goods engines, 14 cents, or 7*d.*, the average being 11½ cents per mile, or 5¾*d.*

This economy has no doubt, however, been materially assisted, by the application of a jet of water from the boiler upon the flanges of the leading wheels of the engines, which has enabled them to pass round the sharp curves of the line with great ease. The coning of the engine-wheels has also been increased, from 1 in 7 to 1 in 6, with great advantage, not only to the working of the engines, but to the permanent way.

The total number of miles run by the nine engines in use during the month of October, 1863, amounted to 22,164; the greatest number of miles run by any engine, is, 3,445; and the whole of the engines have been in use from seven to eight years.

The duty that the engines of this line can perform will

be best understood by the following notes of trains conveyed up the Paso Hondo, Tabon, and San Ramon Inclines:—

Observation 1st.—Train with 16½ inch cylinder goods engine, up Paso Hondo Incline, gradient 1 in 50, with curves of 600 feet radii.

	lbs.	tons.
8 American platform cars, weighing...	113,136	
400 rails, 21 feet long, 84lbs. per yard...	235,200	
Timber, &c.	17,520	
Weight of train	365,856	= 163·33
„ engine	89,616	= 40·00
Total weight ...	455,472	= 203·33

Velocity of train, 10 miles per hour, or 880 feet per minute; the resistance, by experiment, for incline and curve being 70lbs. per ton :—

$$\frac{70 \times 203{\cdot}33 \times 880}{33000} = 379 \text{ H. P.}$$

Tractive force exerted, $70 \times 203{\cdot}33 = 14233$lbs., or rather more than one-fourth of the weight on the driving-wheels of the engine.

Observation 2nd.—Train with 15-inch cylinder passenger engine, up Tabon Incline, gradient 1 in 44, with curves of 600 feet radii.

	lbs.	tons.
2 first-class passenger carriages occupied ...	39800	
3 second „ „ „ ...	63960	
Goods van	20720	
Horse box	12900	
1 loaded wagon	22000	
1 empty „	8000	
Weight of train	167380	= 74·72
„ of engine	83681	= 37·35
Total	251061	= 112·07

Velocity of train, 10 miles per hour, or 880 feet per minute; resistance for maximum gradient and curve, 77·5lbs. per ton;

$$\text{Then} \frac{77{\cdot}5 \times 112{\cdot}07 \times 880}{33000} = 231 \text{ H. P.}$$

and $77{\cdot}5 \times 112{\cdot}07 = 8685$lbs. the tractive force exerted, which is about one-fifth of the weight upon the driving-wheels of the engine.

Observation 3rd.—Train with 15-inch cylinder passenger engine, up San Ramon Incline, maximum gradient, 1 in 55 with curves of 600 feet radii.

	lbs.	tons.
4 first-class carriages	62800	
3 third ,, ,, ordinary	43800	
1 break van	14000	
1 third-class carriage, bogie trucks ...	25000	
Luggage	8400	
450 passengers	63600	
Weight of train	217600 =	97·14
,, of engine	83681 =	37·35
Total weight	301281 =	134·49

Velocity of train, 10 miles per hour, or 880 feet per minute; resistance for maximum gradient and curve, 67·4lbs. per ton;

$$\text{Then} \frac{67{\cdot}4 \times 134{\cdot}49 \times 880}{33000} = 241 \text{ H. P.}$$

and $67{\cdot}4 \times 134{\cdot}49 = 9064$lbs. the tractive power exerted, equal to rather more than a fifth of the weight upon the driving-wheels.

From these observations it appears to result, that the ordinary class of passenger engines, upon inclines of 1 in 44,

with curves of 600 feet radii, can convey a gross weight of train equal to about double their own weight; that similar engines up inclines of 1 in 55 with curves of 600 feet radii, can convey rather more than two and half times their own weight; and, finally, that one of the present goods engines of this line has taken up a gradient of 1 in 50, contained with curves of 600 feet radii, a gross weight of train equal to four times its own weight.

At first, in working the Tabon gradient, considerable inconvenience and loss were caused, by the burning of the break-blocks of the tender. A remedy was applied by allowing water to drip upon them, and being successful, the drivers were led to try the plan of wetting the rails in ascending the inclines, after the engine had passed, so as to ease the train round the curves. The effect proved so satisfactory, that all the tenders are now being fitted with a perforated pipe underneath on each side, so that the outer rail of the curves can be sprinkled with water, and the resistance be thus reduced.

The traffic of this railway, so recently opened, is of course yet undeveloped, but its prospects are encouraging; and although the expense of its construction has been heavy—the cost of the entire line having amounted to nearly 11½ millions of dollars, or about £20,000 per mile, inclusive of rolling stock yet there is a confident expectation that its results will be satisfactory to the country.

The present traffic returns are 23,192 passengers of all classes and 5,000 tons of goods monthly. The receipts amount to 54,168 dollars, so that a return may be expected of about 3 per cent. or 4 per cent., after paying expenses. This amount of profit may be considered sufficient, as the object of the Government is to afford the utmost facilities for the transport of goods in this part of the republic, and a moderate tariff has been

established, so as to bring the benefit within the reach of all, and to distribute the advantages as much as possible. The passenger fares are, for first class, at the rate of $2\frac{1}{4}d.$ per mile. For second class, $1\frac{3}{4}d.$ per mile, and for third class, $1\frac{1}{8}d.$ per mile. For goods there are three classes, the highest being at the rate of $3d.$ per mile per ton, and the lowest at the rate of $2d.$ per mile per ton. Of course, it must be obvious that upon such a line, and in a country where fuel, stores, and skilled labour are so expensive, these rates would be completely unremunerative, but for the position the Government occupies in the undertaking.

The length, cost, plant, and consumption of fuel of the railways of Chile, are shown in the following table :—

Name of Line.	Length in Miles.	Cost of Construction, without Plant.	Plant.			Fuel and Consumption per Mile.	
			Engines.	Carriages.	Wagons.		
		Dollars.				lbs.	cents.
Santiago and Valparaiso ...	114·32	10,734,798	10	36	135	Coal 29·83	cost 11½
Southern	83·50	5,606,281	10	37	154	Wood 63·50	„ 13·61
Copiapo	74·15	2,960,183	14	11	166	Coke 47·19 Wood 1·74	„ 43·19
Chanarcillo	26·00	1,000,000	2	18	81	Coke 67·73	„ 85·00
Coquimbo	40·25	1,040,000	5	6	102	Coal 31·00	„ 14·00
Totals	338·22	21,341,262	41	108	638		

It will be noticed, that the Santiago Railway is worked more economicaly than the others. The difference in the expense upon the Chanarcillo line is due, in a great measure, to its exceptional features. It was originally constructed for a horse tramway, and therefore has inclines of 1 in 33 for $14\frac{1}{3}$ miles, and 1 in 24 for 9 miles, and it attains an altitude of 4,400 feet above the sea. It is now, however, worked by locomotives, constructed by the Messrs. Hawthorn.

Among the general characteristics of the country through which the Santiago and Valparaiso Railway passes, there is much that is attractive and interesting to the general observer. Gold, silver, copper, and plumbago are met with at various points, and the primary volcanic and basaltic rocks are especially well represented. Of the vegetation, the principal objects to be noted are cocoa-nut palms, cacti, the prickly pear, the wild fuchsia, myrtle, and verbena ; also the wild potato, artichoke, mint, sage, and other well-known herbs. In natural history, there is an ample field for study ; whales, pelicans, seals, and penguins are seen upon the coast ; wild swans, geese, and flamingoes are met with at the Batuco Lake ; and, among the rocks of Tabon, the noblest specimens of the condor, together with the diminutive humming-bird, may be seen ; while eagles and vultures are common ; and at times, but only during severe weather, the puma and guanaco (the latter a mixture of the lama and deer), have been observed upon the line.

The social contrasts presented by this railway, are equally interesting. The most primitive means of transport—the pack-horse, or mule, and the hide drawn along the ground by bullocks—are here side by side and in competition with the most recent forms of locomotion ; the earliest and rudest form of plough is employed in the same field with the most modern thrashing machine ; while sun-dried bricks (the clay kneaded by the feet of bullocks), are manufactured in close vicinity to one of Clayton's machines worked by steam-power.

In conclusion, the Author will briefly call attention to the main results of the experience afforded by this work.

With reference to the means for resisting the effects of earthquakes, it is believed that by fish-jointing the permanent way, more security has been obtained. A few years since, a portion of the Copiapo line, where it passed over swampy

ground, completely disappeared, and the rails were lost. The permanent way, in that instance, was spiked to transverse sleepers, and the joints rested in plate-iron chairs, and were readily disconnected.

In bridge constructions, lofty piers of masonry have been avoided, and ironwork substituted ; brick arches, for the same reason, have been considered inferior to plate-iron girders, as being more liable to disturbance by sudden shocks. All abutments of bridges, or retaining walls, have been constructed with battering sides ; extra thickness of work has been allowed, and bond courses of ashler have been introduced at frequent intervals.

By the employment of native fuel, not only considerable economy has been effected, but the superiority of Chilian coal has been manifest over the English coal, as introduced into the country. Its qualities for the production of steam are beyond all doubt ; but, though highly inflammable, it requires so large a supply of atmospheric air for its perfect combustion, that the fire-doors of the locomotives are never closed.

The application of the hot-water jet upon the leading wheels of the engines, has so facilitated their passage round curves, that, provided sufficient play be allowed to the trailing wheels not only is the resistance diminished, but the tires are preserved, and bogie trucks, with all their various inconveniences, seem to be unnecessary.

Again, the application of moisture to the rails from the tender, in passing round abrupt curves upon steep gradients, the rails for the engine remaining dry, reduces the resistance due to curvature in a sensible and important degree ; and by the same means the break-blocks, in descending inclines, can be prevented from igniting.

An attempt to adapt screw piles as foundations for a bridge upon a quicksand, was unsatisfactory in its results, it having been found impossible to force the pile down to a sufficient depth, in consequence of the sand becoming jammed in the screw. Cast iron or timber piles had therefore to be substituted.

Similar long and steep inclines to the Tabon, combined with curves of 600 feet radius may be introduced without hesitation when necessity requires their adoption ; even without any extraordinary and special locomotive arrangements being requisite, until the augmentation of the business of the line demands it.

These remarks are presented in the belief, that it is only from the comparison of practical results, with the experience of others, that the true principles which should govern the Engineer in the formation of his plans can be ascertained ; and also as a slight acknowledgment of the advantages derived by the Author, from the publication of similar information by the Institution.

The Paper is illustrated by a map of Central Chile, showing the Santiago Railway ; by complete plans and sections of the entire line ; by a plan and section, to a small scale, of the Tabon Incline ; by a drawing of the Marquis Viaduct ; and by various photographic views ; as well as by an Appendix comprising a Table of the straight and curved lines upon the Tabon Incline, with the gradients upon each.

(Extract from Engineering 26th November 1869, *Page* 355.*)*

SOMETHING NEW IN LOCOMOTIVES.

In our number for April 2nd, 1869 page 232, under the heading of "Higher and Higher" we stated that "Mr. Thomas Harrison, one of the concessionaires of the Cerro de Pasco Railway of South America, has lately visited England. His line will have a summit 14,200 feet above the sea, or nearly the elevation of Mont Blanc. Approaching from the sea in the direction of the line there are 36 miles of road through and over mountains and precipices, and along which only mules can travel. How are the locomotives to be carried over this road? Every thing, it would seem, should be carried in pieces, the boiler separated from the fire-box, the tubes in a fagot by themselves, &c. Some clever scheming will be required."

The solution of this problem was entrusted to Messrs. Manning, Wardle, and Co., of the Boyne Engine Works, Leeds, whose reputation as designers and builders of light locomotives for special purposes is well known. The line is 3 feet 6 inches gauge, and is laid with flange rails of 45lb. per yard, the radius of the sharpest curve is 800 feet, the steepest incline is 1 in 37, and greatest gross load about 80 tons, so that the duty to be performed by the engines was not so exceptional as the difficulty of transporting them for some 70 miles (not 36 as above) upon the backs of mules over the Cordilleras of the Andes mountains. The maximum weight allowed for any one piece or package was 300lb., and no object was to exceed 7 feet in length. The engines have outside cylinders 12 inches diameter, and are carried upon six wrought-iron coupled wheels with steel tyrés; the tanks are of the "saddle" from resting upon the boiler barrels.

As we expected, "some clever scheming" has been required to conform to the stipulated weights, of course the boilers, tanks, frames, and wheels, and in fact all heavy parts go out in pieces; for instance, the cylinders and steam chests, usually cast in one, are in this case made in five pieces, the frames are made in sections, and the wheels, tyres, and axles are all separate. Messrs. Manning, Wardle, and Co., have also constructed a fixed workshop engine, and boiler, together with a wheel lathe, drilling machine, lathes, blowing fan, and smith's hearths and tools. In this case the maximum weight allowed was only 150lb. for each package. This necessitated the fast headstock of the wheel lathe being made in no less than fourteen pieces, and yet these are so contrived that an ordinary observer would not notice anything special about it. A staff of boiler makers and fitters in charge of a leading erector have been engaged to go out to Peru to erect the engines on their arrival. So far as we know, these are the first locomotive engines which have been sent out from this country in such small pieces. They have been entirely designed and built by Messrs. Manning, Wardle, and Co., and have given every satisfaction to Mr. Edward Woods, the consulting engineer to the Cerro de Pasco Railway.

RAILWAYS IN NORTH AMERICA.

Remarks by Mr. Zerah Colburn, after the reading of the paper at the Inst. C. E., by Captain Tyler, R. E., on "The Festiniog Railway" (Vol. 24, p. 386.)

Mr. Zerah Colburn said this Paper raised the question, how small could a locomotive be made to give practically useful work? In 1852 the contractor for a portion of the works on the Great Western Railway of Canada employed the steam excavator, which no doubt many present had seen in former

days on the Eastern counties line. For that purpose he proposed to lay the temporary line on the 3 feet 3 inches gauge, and wagons were built to hold each 15 cwt. as a load, Mr. Colburn designed and built a small 4 wheel tank engine for working those wagons, and six other similar engines were afterwards built. The tank was placed under the boiler between the frames, and as the gauge was so narrow, the fire-box was placed behind the driving wheels, and to correct the over hanging weight, the tank was carried as far forward as possible. These engines weighed 6 tons only, with fuel and water, and could be easily taken apart, for carriage over common roads, into three principal portions, of which the heaviest weighed hardly more than 2 tons. The cylinders were 9 inches in diameter, with a length of stroke of 16 inches; and the wheels, of 3 feet diameter, were placed 4 feet 6 inches apart from the centres. The engines worked well, although of course only at moderate speeds.

(Extract from Engineering, 8th October 1869, *Page* 238.*)*

CANADIAN LIGHT RAILWAYS.

An example of enterprise and energy is being just now set by the merchants of the city of Toronto, in Canada West, in combination with the farmers of the surrounding districts, well worthy of imitation in other districts, equally in need of that development of trade and increased prosperity which the establishment of communications must bring about.

For some years it had been felt that the existing railways, running as they do nearly due east and west from Toronto, the capital of the Province of Ontario, were doing comparatively little towards opening up the rich farming country, and im-

mense lumbering districts lying to the north-east of the city, or towards affording proper facilities for the large existing traffic of the rich and fertile counties of Grey and Bruce, lying to the north-west.

Canadian railways were at a discount in the English market, rendering it futile to seek for capital there, and the leading merchants of Toronto, forming themselves into provisional boards of direction, and associating with themselves delegates from the country districts, therefore determined under the advice of their engineers, Sir Charles Fox and Sons, to profit by the experience gained in Norway, India, Queensland, and elsewhere, and to construct light yet efficient railways, sufficient to conduct the traffic for a long term of years at any rate, and at such a moderate outlay as would bring the whole enterprise within the scope of their own resources.

Having succeeded, after much opposition from existing railway interests, in carrying two charters through the legislature in the spring of 1868, active steps were taken to bring the matter before the City Council of Toronto, the councils of the different townships, and the inhabitants generally, and the result has been that in the present summer of 1869 two companies have been organised, under whose auspices the railways are being rapidly proceeded with.

The Toronto and Nipissing Railway Company is at present constructing a railway from Toronto for a distance of 85 miles to tap the Gull River navigation, with a branch of 18 miles to the town of Lindsay, and is intended hereafter to be extended 120 miles still further towards the north.

Towards the construction of the first section of 85 miles, bonuses have been voted by the various municipalities, amounting to 83,125*l.*, on nearly 1,000*l.* per mile, this being a clear gift to the company.

The Toronto, Greg, and Bruce Railway Company is at present constructing a railway from Toronto to the Garafraxa Road, a distance of 70 miles, and steps are being taken for an immediate extension to the shores of Lake Huron at Kincardine, and Owen Sound, giving a total length of 200 miles. This company will also enjoy bonuses from municipalities amounting to about 1,000*l.* per mile.

The remaining capital is being raised by stock subscribed in Canada, and upon the debentures of the companies.

The country through which these lines will run is generally of an undulating character; intersected with heavy gullies through which the main streams flow, and on the western lines there is a heavy range of hills to be surmounted. It has been found necessary, in order to reduce the earthwork within reasonable proportions, to make use in some instances of gradients of 1 in 50, with here and there curves of 350 feet radius. In this way, even in the broken country and amongst the spurs of the hills, the average amount of earthwork has been reduced to 15,000 cubic yards per mile, chiefly of soft soil, with boulders here and there. The embankments are 12 feet 6 inches, and the cuttings 15 feet 6 inches wide at formation level, the latter including ditches. The line will be fenced throughout with timber fences and cattle guards at the crossings. Immediately upon the land being cleared for each section the telegraph will be erected, thus placing the chief engineer in direct communication with his staff. Fences will be placed at different angles in the neighbourhood of the railway to intercept the snow drifts, a system adopted with great success by Mr. Carl, Pihl, the engineer of the Norwegian Government. The bridges will be constructed with abutments and piers of rubble masonry, where possible, but in some cases timber cribs filled with boulder stones will be used. These latter properly laid form both a

substantial and durable construction, and are economical. The superstructure will be of timber, the main trusses being of white oak, of a form slightly modified from that known as the "Howe" system. The spans will vary from 30 to 80 feet. The width between parapets will be 11 feet. The permanent way, which has been too generally dealt with in Canada, as if it were of secondary importance, is really the most important item of the whole, as upon its efficiency under most adverse climatic influences depend not only the economical maintenance of the works, but the actual safety of the traffic. The great range of the temperature in Canada brings about a large amount of contraction and expansion, whilst for several months' in the year the road-bed is frozen to the hardness of rock, and it becomes impossible to pack or adjust the sleepers, the plan usually adopted for removing inequalities in the road being to pack with small wedges between the flange of the rail and the surface of the sleepers. The winter breaks, up very suddenly, and then the ground, rendered rotten by frost and melting snow, gives way under the sleepers in all directions, and for some time travelling becomes at any rate on some of the lines positively dangerous. These climatic effects are very difficult to deal with, but are in many instances aggravated by the use of rails of very bad quality, fished most imperfectly, if at all, and secured by dog spikes only, and still more by the use of an exceedingly small quantity of ballast. It is intended on the railways in question to use either iron rails weighing 40lb. to the yard, or probably on a portion of the lines, Bessemer steel rails weighing 36lb. to the yard, in either case flat bottomed, and laid vertically (without the usual inward cant) to a gauge of 3 feet 6 inches. These will be laid upon sleepers of red beach, white oak, tamarac, and chestnut, 7 feet 6 inches long, 8 in × 5 in. scantlings, and 2 feet 6 inches apart, centre to centre, there being a sleeper under the joint.

The rails will be fished at the joints with Adams' bracket fishes 14 inches long, secured by 4 fish bolts, and to the joint sleeper by 4 fang bolts, with an extra length of thread to allow of the rails being wedged up, if necessary, to adjust the road in winter, the turnouts will be by means of improved sliding rails, ordinary switches being liable to jam up in snow storms and frost. Great care will be taken to use ballast of good quality, and to an extent of not less than 3000 cubic yards per mile of single line. With a view to economy, the sleepers, fencing, and bridge timbers, are delivered along the line during the winter months, whilst the snow permits of sledges being used, the earthwork, permanent way, laying and ballasting being chiefly carried on in summer. The stations will be of a simple yet tasteful design of timber, and will be placed about 5 miles apart. At the Toronto terminus, extensive arrangements will be made for the shipment of lumber and grain, and it is probable that an union station for passengers will be established, common to the five companies, which will run into the city. The railways will be generally worked by locomotives smilar to those used in Queensland, weighing from 20 to 22 tons, including wood and water, having six driving wheels, 3 feet 3 inches diameter, so arranged as to give a rigid wheel base of only 7 feet, and a pair of leading wheels, 2 feet diameter, fitted to a Bissell bogie truck. The tyres will be cylindrical and not coned, of solid steel. The cylinders will be 11 inches diameter and 18 inch stroke. The heating surface will be from 550 to 600 feet. The fire-box will be of copper, so as to be hereafter applicable for burning coal; the whole of the motion will be of Bessemer steel. The weight on each driving wheel will be 3 tons, and on each of the leading wheels about 2 tons. The tender will weigh 10 tons when loaded, and will have four wheels 2 feet diameter, with only 4 feet 6 inches rigid wheel

base. The spark arresters will be of a form lately adopted in Queensland. The locomotives will be fitted with American cabs, and pilots, or cowcatchers. It is probable that smaller engines, weighing, say, 15 tons, may be adopted for passenger trains. The rolling stock generally will be of the American pattern, but much reduced in cost and weight; the wheels will be 2 feet diameter of American chilled cast iron. The springs will be hung to brackets inside the frames, thus bringing down the centre line of buffers to within 2 feet of the rails. The admirable central coupling and buffer of the Norwegian Government Railways will be used. The outside width of the stock will be 8 feet. The length of the passenger carriages will be 32 feet, and of the goods wagons 24 feet, each on six wheels, fitted with Clarks radiating axles, which, after being tried for some years side by side with other systems, on curves of 330 feet radius, are found to take sharp curves more easily, and require less tractive force than those on any other plan. The stock will be fitted with powerful brakes. Carr's system of lubrication will be used throughout the stock. The speed on these railways will be about 20 miles an hour, including stoppages. The works are being carried out partly by the companies and partly under contracts divided into short sections, and let to local contractors at cash prices, under the superintendence of Mr. Edmund Wragge, lately resident engineer on the Victoria Bridge widening, who has been appointed chief engineer in Canada to both the companies, and they are estimated to cost, including land, rolling stock, stations, and all other expenses, 3000*l.* per mile of single line. It is intended, with the exception of the locomotives, rails, and fastenings, to use Canadian materials throughout, and the whole of the staff of the companies, with the exception of their chief engineers, are Canadians. It is hoped, therefore, that these railways will

solve the problem so important to the new Dominion of Canada, of constructing her lines of communication with her own men, materials, and money, and if these lines, as is confidently expected, prove, from their small cost, yet efficient construction, financially successful, they will lead to other railways, destined to develope the immense mineral and agricultural resources of the north-west of Canada.

Remarks by Mr. Mendes Cohen of New York, U. S., after the reading of Captain Tyler's paper before the Inst. C. E. on "Railway Gradients and Curves." (*Vol.* 26, *page* 330—331.)

Mr. Mendes Cohen, of New York, would give the results of his experience in working the Baltimore and Ohio Railway, through Virginia. The gradients on that line were generally heavy. On the mountain division, 60 miles in length, there were 37 miles varying but slightly from 1 in 45, at which maximum there were 17 miles in one continuous gradient. The goods traffic was worked by engines weighing, exclusive of tender, about 27 tons, on eight connected chilled wheels 43 inches in diameter, with cylinders of 19 inches diameter and 22 inches stroke, hauling nine cars weighing about 135 tons. In addition to these there were other and much heavier gradients of a temporary character, adapted for the purpose of working over the tunnel ridges during the progress of the construction of the tunnels, to continue the line without waiting for the completion of the tunnel-work. In the first instance the gradient adopted was 1 in 10 as a maximum, and it was not intended to work this temporary line with locomotives. The line was built with a view of hauling car-loads of iron across the mountain by horse-power, and continuing the construction of the works

on the other side. However, when the line was laid, it was determined to try the working with locomotives. The engines just described were tried on this gradient and readily took up a load of one car weighing about 14 tons. Under favourable circumstances they could take up two, but one was the usual load. He had ridden over that line on the engines but otherwise had not much experience in the working. As the construction of the line progressed westward, there was another tunnel on which he had been engaged as an assistant in the engineering department in the year 1852. Owing to delay in the tunnel, the Chief Engineer, Mr. Benjamin H. Latrobe, directed the construction of a temporary road across the hill. It was a work of some difficulty, as the slopes of the hill were very abrupt, and he was instructed by his chief to see what he could do in the way of bringing the line down from the summit to the foot of the hill, with a limit of gradient of 1 in 16, and reversing the direction as often as was necessary. The descent of the summit on the western side was made with five reversals, the narrowness of the ravines and the general shape of the ground not always affording room for curves of even the minimum radius of 300 feet. The reversal was effected by what was termed a Y, from its resemblance in plan to that letter. With this arrangement the slope of the hill was descended on a gradient of 1 in 16 between one pair of Y's, and 1 in 20 between the next pair, and so on alternately, the object of this being to secure the proper protection of the fire-box sheets, which might have been exposed had the rear of the engine been uppermost on the heavier gradient. The line was worked with five reversals on one side and two on the other for a distance of 2½ miles on both sides of the hill, over which the engines carried three cars of 15 tons each. The load was never increased beyond that, because the shape of the ground did not admit of

getting longer trains upon any of the Y's. The traffic was carried on for five or six months, till the tunnel was completed. At a later period it was necessary, for a second time, to use the temporary track over the tunnel where the gradient of 1 in 10 had first been tried. On this occasion the gradient was reduced to 1 in 20, or equal to 260 feet per mile, and this Mr. Cohen himself worked with the same engines, which carried up from 65 to 70 tons load. In fact the whole traffic—mails, passengers, and goods—of one of the great American through lines was carried on by this way for many months during the arching of the tunnel. There was no difficulty in ascending the hill; the only difficulty lay in the descent. In effecting this, besides the application of breaks to all the wheels of the train, the engine was reversed and allowed to descend without using steam thus pumping air through the cylinders. The accumulating pressure against the pistons was relieved by valves placed on the steam-chests, and regulated from the foot boards. The engines were kept, on the heaviest portion of the gradient, on the lower side of the train, to guard against the breaking of the couplings, as well as with reference to the fire-boxes. There were some instance of the trains breaking away, from the failure of the breaks, and some little damage had been done; but no case of serious accident occurred during the whole time.

RAILWAY IN BELGIUM.

Remarks by Mr. Robert Mallet, M. Inst. C. E., after the reading of Captain Tyler's paper on "The Festiniog Railway" before the Inst. of C. E. (Vol. 24, page 375.)

Mr. Robert Mallet said, as yet no mention had been made of another narrow gauge line, which had been a long time in successful operation, viz., that between Antwerp and Ghent, the

gauge of which, he believed, was only 2 feet 3 inches. He could not give the precise particulars of the rolling stock, but could state generally, that the carriages were wider than those on the Festiniog Railway, and that they carried heavier loads.

RAILWAY INCLINE IN TURKEY.

Remarks by Messrs. Mallet, Crampton and Drew, after the reading of Captain Tyler's paper on "Railway Gradients and Curves" before the Inst. C. E. (Vol. 26, page 381—382)

Mr. Robert Trefusis Mallet referred to a tramway constructed for Mr. Crampton on the Ottoman Railway on which he had been engaged, which he believed showed the extreme limit of what could be done on inclines by ordinary locomotives without special means of adhesion being applied, as in the case of the central rail on the Mount Cenis line. There was a gradient of 1 in 11 with curves of 500 feet radius. One difficulty was experienced in consequence of the extreme severity of the gradient; that was, the necessity of turning the engines at the summit, to avoid laying the fire-box bare by the gravitation of the water to the lower end. The engines could only pull one loaded wagon up this incline. The results were not brought forward as an instance of the greatest economy that might be obtained by using special engines, but rather to show what could be done with existing plant. He presented to the Institution diagrams showing the section of the tramway and the statistics of the engines used.

Mr. T. R. Crampton said there was nothing peculiar about the incline just referred to, but it had acted most perfectly. The gradient was 1 in 11 for a length of 2,400 feet, 600 feet of which had curves of 400 feet radius, descending about the same

distance with inclines of 1 in 15 and 1 in 20, the total length being about one mile. About 100 tons per day were taken over this gradient of 1 in 11, and about 10,000 tons had been carried over the whole length up to the present time. The gross load was about 23 tons, of which the engine weighed 10 tons, leaving 13 tons of working load behind the engine. The adhesion was about one-fifth, so that the maximum was almost attained.

Mr. E. A. Drew remarked that the cost of working over the whole of these inclines—that was up half a mile of 1 in 11, and down half a mile of an average gradient of about 1 in 15, over which the loads and return empties were transported—was at the rate of two shillings per ton per mile. That tramway was successful, inasmuch as it served the end intended, by transporting, during the six months it was in operation, about 10,000 tons of material, which could not possibly have been carried by any other means so economically. Taking into consideration the price of coals there, and the difference in the wages of skilled labour, it was probable the same end under similar circumstances could have been achieved in England at half the cost. The engine was not made specially for this incline, but was an ordinary contractor's tank engine, built by Mr. Hughes, of Loughborough, the principal dimensions of which were—

Diameter of Cylinders	11	inches.
Length of stroke	18	,,
Diameter of wheels	30	,,
Wheel base	54	,,
Four wheels coupled		

The weight of the engine complete was 10 tons.

With a pressure of steam of 90lbs., to 100lbs. per square inch, the gross weight taken up the incline of 1 in 11 was 23 tons, including the engine.

STEEP RAILWAY GRADIENTS.

(Extract from Engineering, dated 1st January, 1869.)

At the present time when attention is being again directed to the unsatisfactory working of the Mont Cenis engines with their horizontal gripping wheels and attendant complications, it is worthy of note that during the construction of the Ottoman Railway, Mr. T. R. Crampton made regular use of, and worked by an ordinary contractor's engines, a tramway laid for a length of 800 yards to a gradient of 1 in 11. This tramway was altogether about a mile long, and for 800 yards of this length it rose, as we have said, at an inclination of 1 in 11, afterwards descending for about the same distance with inclines of 1 in 15 and 1 in 20. About 200 yards of the gradient of 1 in 11 consisted of curves of 400 feet radius. The tramway was employed for the conveyance of materials to be used in the construction of the main line, and during six months about 10,000 tons were carried over it. It was worked by an ordinary contractor's locomotive, built by Mr. Hughes, of Loughborough ; this engine having cylinders 11in. in diameter by 18in. stroke, and two pairs of coupled wheels 2ft. 6in. in diameter, placed 4ft. 6in. apart from centre to centre. The weight of the engine in working order was 10 tons, and it drew behind it a load of 13 tons up the gradient of 1 in 11. The pressure of the steam was from 90lb. to 100lb. per square inch.

On an incline of 1 in 11, the resistance due to gravity would be 203·64lb. per ton, and taking the engine friction at

18lb. per ton, and the wagon friction at 10lb. per ton, we have the following total resistances to be overcome by the engine in ascending the gradient :

		lbs.
Resistance due to gravity :	23 tons at 203·63lb. per ton = ...	4683·5
Engine friction :	10 tons at 18lb. per ton ...	180
Wagon friction :	13 „ 10 „ ...	130
Total	... ...	4993·5

or, say, 5000lb. The weight available for adhesion was 10 tons, or 22,400lb., which would be diminished by one-eleventh on an incline of 1 in 11. The actual adhesion weight available in the incline would, therefore, be,

$$22{,}400-\frac{22{,}400}{11}=20{,}364\text{lb.},$$

and the adhesion must, therefore, have amounted to very nearly one-fourth of the load on the wheels. An engine of the dimensions above given would develope a tractive force of,

$$\frac{11^2\times 1{\cdot}5}{2{\cdot}5}=\frac{121\times 1{\cdot}5}{2{\cdot}5}=72{\cdot}6\text{lb.},$$

for each pound effective pressure per square inch on the pistons ; and to overcome the tractive resistance of 5000lbs. this effective pressure must thus have been $\frac{5000}{726}=68{\cdot}6$lb. per square inch. This pressure on the piston could, of course, be readily maintained by a boiler pressure of 90lb. per square inch.

RAILWAY IN THE MAURITIUS.

Remarks by Mr. T. A. Longridge, M. Inst. C. E., after the reading of Captain Tyler's paper on "Railway Gradients and Curves" before the Inst. C. E. (*Vol.* 26, *page* 371.)

Mr. J. A. Longridge said, the subject of the Paper was not upon the construction of the Mont Cenis or any other railway through the Alps, but upon the best way of working steep gradients, supposing they were absolutely necessary; and on that subject he would give the results of his experience. He had laid out a railway in the Mauritius some years ago, which was subsequently executed; and, though not worked by himself for passenger traffic, he had worked it for ballasting and for the transport of materials. The ruling gradient of that line was 1 in 27. The ballast-trains consisted of twenty wagons, in fine weather, with an engine at the front and back, which he believed was a safe way of working these heavy gradients, because it rendered them, to a great extent, independent of the breaks. Each of these engines weighed 37 tons, and each truck-load weighed 13½ tons, making a total load of 270 tons, besides the two engines weighing 74 tons. It was found that in fine weather, when the rails were dry the inclines of 1 in 27 could be ascended, with wheels 3 feet 9 inches in diameter, at about 8 miles an hour; but when the rails were wet from rain or dew, the load had to be reduced by four, or six, or more trucks: the coefficient of fiction, under these circumstances, came out as one-fifth. There could not be a doubt that it might be worked with a co-efficient of from one-fourth to one-fifth; but it was not at all desirable that such a coefficient should be depended upon, because, on a dewy or damp morning, the train might come to a standstill.

RAILWAYS IN ITATY &c.

Extract from a paper by C. R. Drysdale, on "Railway Incline Planes" read before the Institution C. E. describing the Semmering and Giovi Inclines, with remarks by Captain Moorsom, John Hawkshaw, M. Inst. C. E. and Chas. Vignoles, M. Inst. C. E. (Vol. 15 *p.* 350, *&c.)*

The Semmering Incline.

The works were finished and the double line of rails laid, in May 1854, by the Engineer Carlo de Ghega. On the northern side, the valley is formed of a bed diluvim, lying on the flank of a mountain of Greywacke slate. At Klamm, the works become steep and abrupt; and the northern side in general, is much more rugged than the southern, which descends with a regular gradient, with but few cuttings, or embankments of importance. With the exception of the Valleys of Adlitzgraben and Kalte Rinne, where the rocks are calcareous, the whole formation is mica schist, with here and there, and outcrop of dolomitic rock. The site appears, upon the whole, to be remarkably well suited for a railway, since the tunnels and viaducts are comparatively short. There are, however, thirty curves of 10 chains radius, of about 4 miles in entire length, and thirty-eight curves of 14 chains radius.

The most interesting works are the Viaducts of the Valley of Adlitzgraben, and of Kalte Rinne; the two over the streams Wagner and Jäger-Graben; that over the river at Swartzaü and the lower Adlitzgraben Viaduct; and the tunnels of Semmering and Weinzettelwand.

The Viaduct of Adlitzgraben has upon it, a gradient of 1 in 50; the radius of the curve is 10 chains; the length, 498 feet; and extreme depth, 78 feet: it is composed of 8 arches of

50 feet span. The Viaduct over the Kalte Rinne is composed of two superimposed ranges of arches: the gradient of the line is 1 in 80; the radius of the curve, 10 chains; the length, 600 feet; and the extreme height, 150 feet: there are 5 arches of 40 feet span on the first range, which is 69 feet high; in the second range, there are 10 arches of 48 feet span, and the height of the stage is 80 feet. The Viaduct over the Wagner-Graben has two ranges of arches; the gradient is 1 in 47; the radius of the curves, 9 chains; the length, 470 feet; and the greatest height 127 feet. The lower range has five arches of 30 feet span and 56 feet in height, and the upper has nine arches of 40 feet span and 70 feet in height. The Viaduct at Swartzaü has a curve of 14 chains radius: it is 744 feet long; its greatest height is 80 feet; and it has 5 arches of 66 feet opening, in the middle, and eight arches of 32 feet opening, at the sides. The Tunnel of the Semmering is 72 chains long: it is straight, with an almost imperceptible gradient; its greatest depth is 374 feet, and it is lined throughout with masonry. Nine shafts were sunk for this tunnel, and five of them were left open for air shafts. A considerable quantity of water was encountered in its construction. The total length of tunnelling in the Semmering Pass, is 213·5 chains, of which only 9 chains are without lining.

The total length from Payerbach to Murzzuschlag is 21·51 miles; the length of the level portions, 2·04 miles; and that of the other parts, 19·47 miles. The gradients are:—

From Payerbach to Eichberg	...	1 in 46	for	3·848	miles.
,, Eichberg to Klamm	...	1 in 40	,,	2·529	,,
,, Klamm to Breitenstein	...	1 in 47	,,	3·259	,,
,, Breitenstein to Semmering	...	1 in 54	,,	3·574	,,
,, Semmering to Spital	...	1 in 50	,,	4·454	,,
,, Spital to Muzzuschlag	...	1 in 50	,,	3·856	,,

The average gradient from Payerbach to Semmering in 1 in 47, for 13·210 miles, and from Semmering to Murzzuschlag, 1 in 50, for 8·310 miles.

Payerbach is...	... 1,562 feet above the sea.	
Semmering ...	... 2,887 ,,	,,
Murzzuschlag	... 2,182 ,,	,,

From Payerbach to Eichberg, the curves range from 9½ to 14 chains radius, almost continuously, with only a short piece of straight line. From Eichberg to Klamm, is the most unfavourable portion of the line ; having a gradient of 1 in 40, and consisting of 14 curves of 14 chains radius, with scarcely any straight lengths. From Klamm to Breitenstein, there are 16 curves of about 9½ chains radius ; and the part from Breitenstein to Semmering, is very similar.

The permanent way is constructed in the following manner :—Longitudinal larch sleepers are laid upon a bed of broken stone 6 inches in thickness, which is then covered with 6 inches of gravel, well beaten down. Upon these longitudinal sleepers, are placed transverse pine sleepers, at intervals of about 3 feet apart ; and on the cross sleepers the rails are placed upon flat chairs at the point of contract with the sleepers. The rails are of the T form, and weigh 88lbs. per yard. The spaces between the sleepers are filled with gravel ballast.

Forty years ago, it was doubted whether a locomotive with plain wheels, would adhere to the rails sufficiently to enable it to move itself, and subsequently, inclines of 1 in 120, or 1 in 100, were considered as the limits to the powers of the locomotive ; but now a line is constructed over the Noric Alps, with inclines of 1 in 40, and with curves, which were until lately considered complete barriers to the passage of locomotives.

M. Engerth says:—"In the construction of a mountain line such as the Semmering, without any doubt, railways

entered on a new phase, and consequently, there was a necessity for new experiments upon locomotives also. There have certainly occurred on other lines, short and steep gradients; but these have been so short, as scarcely to necessitate any change in the locomotives, from those used upon the level line. But a line of 21 miles, in a region of snow and ice, required something new, which should be fit to cope with the peculiar difficulties of the situation." Impressed with this idea, the Austrian Government, in 1850, proposed a prize for the best locomotive, constructed in accordance with the stipulations; and although none of those sent to the competition, performed all the conditions required, yet the effect of the experiments was to bring out the requisites for an engine qualified to accomplish them. The locomotive 'Bavaria' won the prize, at this competition, but as it appeared, that the chief cause of its greater powers, was the application of an endless chain to connect the wheels, a further set of experiments was made on this engine, when it was found, that the chain continually got out of order, and frequently broke, so that it was eventually abandoned.

M. Engerth, in his account of the different locomotives send for competition, has been very circumstantial, and certainly, has carefully studied the principles and the facts elicited, and has endeavoured to arrive at a sound conclusion; he examined, seperately and in detail, each one of the designs sent in by the various locomotive Engineers, and then appears to have selected those modifications, which appeared most suited for the exigencies of the Semmering Pass.

The following is a brief description of the type of engine, now in use upon the Semmering :—The fire-box surface is 75 square feet, with 189 tubes of 2 inches diameter and 15 feet 7 inches in length, giving a tubular heating surface of 1,585 square feet. The total heating surface is thus 1,660 square feet, which

gives, as will afterwards appear, $5\frac{1}{2}$ square feet, per effective horse power. The grate area is 12·6 square feet, or $\frac{1}{130}$th of the heating surface. The total weight of the engine, filled and loaded, is $55\frac{1}{4}$ tons. This load is thus distributed:—$13\frac{1}{2}$ tons on the leading-wheels, $12\frac{1}{4}$ tons on the middle wheels; and 13 tons on the driving-wheels; or $38\frac{3}{4}$ tons on the three pairs of coupled wheels. There were also $16\frac{1}{2}$ tons equally distributed on the two trailing-wheels, which weight was, at first, detached from the other, but was subsequently brought to assist the former, by means of axles, with toothed wheels, keyed on them. The diameter of the cylinders is 18·7 inches, the stroke is 25 inches, and the diameter of the wheels is 3 feet $7\frac{3}{4}$ inches. The last two axles are held in a peculiar description of 'Bogie,' which also contains the driver's platform and the fuel. The water is carried in tanks at each side of the boiler, which is elliptical in section, and on a platform, supported by brackets, bolted on the framing of the six driving-wheels: by this arrangement, the whole weight of the engine and of the water is used to insure adhesion to the rails. The cylinders are outside the framings, with the valve-gearing on the outer sides; the eccentrics are carried on a kind of overhanging crank.

The Giovi Incline was constructed to surmount the Apennines, near Geona,—one of the great difficulties of the railway from Turin to Genoa,—and its execution is a proof of the mechanical skill and energy of the Sardinian nation. The Engineer of the line, from whom the following information is obtained, made many experiments on the subject of locomotives, as he had to contend against a strong party, who were favourable to the use of stationary engines for steep inclines. He says, the locomotive engines have been running on the line since December 1853, and have given such satisfaction, that it would not be desirable to alter them, except in some minor

details, and he thinks the system adopted on the Giovi better than that used on the Semmering.

The Giovi Incline commences about 7¾ miles from Genoa, at a point, 295 feet above the level of the Mediterranean. It ascends thence, for about 6 miles, to an elevation of 1,184 feet being an average gradient of 1 in 36. The gradients of this incline are as follows, commencing from above :—

1 in 36 for	2·14	miles.
1 in 29 „	1·33	„
Horizontal	·08	„
1 in 29 for	·19	„
1 in 36 „	·93	„
1 in 50 „	1·33	„

The length of tunnel is 2·55 miles; the depth of the shafts is about 600 feet; and the cost per yard forwarded, was £118. The gradients have curves of the minimum radius of 20 chains, which, it may be remarked, is a very much better minimum than that of the Semmering, which is only 9 chains.

The locomotive power employed for ascending the incline, consists of two engines of the same size, constructed by Messrs. Robert Stephenson and Co., of Newcastle, each carrying its own coke and water, and resting on four coupled wheels, moved by piston-rods, from outside cylinders. The diameter of the wheels is 3 feet 6 inches; that of the pistons is 14 inches, with a stroke of 22 inches. The two locomotives are bolted together, so that the fire-boxes are opposite to each other, and the driver stands on a common platform; when filled and loaded the two engines weigh 55¼ tons; of this weight, the wheels nearest to the fire-box, carry about 7 tons each, and the others, about 5 tons each.

In fine weather, the locomotives will carry up about 100 tons, and in the worst weather, never less than 70 tons, at a

speed of 15 miles per hour.

Miles of passenger trains	613·30
Do. goods trains	2,283·57
Total	2,896·87

Weight in tons, of Trains lifted up.

Passenger trains	6,467 tons
Goods trains	28,738 „
Total	35,205 tons.

Dead weight carried $\frac{5}{8}$ths of a mile: in tons.

Not including the engine	352,050
Including the engine	585,150

Coke consumed in ascending, including stoppages ... ... = 195 tons.

Consumption of coke per ton per mile, is—

Not including engine... ...	1·94lbs.
Including the engine	1·16 „

The fuel consumed by the engine from the bottom to the top of the incline, 6 miles, with a gradient of 1 in 36, is 8·27 cwts.

Remarks.

Captain W. S. Moorsom said, he believed, that the Lickey Incline on the Birmingham and Gloucester Railway and the Dainton Incline on the South Devon, were the only two in Great Britain, which were at all important with regard to large, or speedy traffic, as they were in the middle of lines, over which express trains passed without necessarily stopping. It was difficult to obtain from those who had the management of the working of railways, precise data for instituting a comparison with those given in the Paper. This chiefly arose from the ac-

counts being kept for commercial purposes only, and thus giving the general results of the working of the entire line, without reference to such portions as were now under consideration. From such data, however, as by favour of the managers, he had been able to collect, and from his own experience on the subject, he would endeavour, as far as was practicable to establish a comparison. On the Semmering Incline, the average load per train was given as 165¼ tons, which was moved at a speed of 11¼ miles per hour, up an incline of 1 in 40, with a consumption of wood of 340lbs. to the mile: the pull of the engine might, therefore, be taken at 10,300lbs. On the Giovi Incline, which was 1 in 36, the greatest load, of 150 tons, including the two engines, was moved at a speed of 15 miles per hour; the coke used was 174lbs. per mile, and the pull of the engine, under those circumstances, would appear to be 10,600lbs: there was thus, a rather steeper incline and a little more force exerted by the engine, with a greater speed, than in the case of the Semmering Incline. The Lickey Incline was 1 in 37, and two engines were employed,—the bank engine of 35 tons, and an ordinary goods engine of 32 tons. Taking the average load of goods trains, as furnished by Mr. Kirtley, to be 307 tons, this was the weight which might be assumed to be moved up that gradient, at an average speed at 6½ miles per hour, with a consumption of coke, of 80lbs., per mile. The question of consumption of coke was subject to some difficulty the amount he had given, was an average upon the total quantity consumed by the bank engines, as no separate account was kept with regard to this incline alone. It resulted from these conditions, that the two engines together exerted a force of 21,800lbs., or nearly double that on the Giovi and Semmering Inclines, while the speed was about one-half less. It appeared, from statements, furnished by Mr. Gooch, that on the

Dainton Incline of the South Devon Railway, the average load of a goods train, including engines, was 215 tons which was moved at the rate of 11½ miles per hour. He confessed, that from his own observation, he should not have thought the speed was so great. The gradient was 1 in 45, and the quantity of coke consumed, was 58½lbs., per mile. This, again, was the average consumption per train mile, but on that particular portion of the line, he believed it would be, at least, 50 per cent. more. In this case, the pull of the engine was about 12,500lbs.

It was stated in the Paper, that the Austrian Engineers, in considering the weight to be given to the engine for working the inclines, thought, that adhesion could not be obtained, without a weight on the wheel, equal to eight times the force of the pull of the engine. He ventured to say, that it was practicable to ascend even greater inclines, with a weight equal to only five times the drag of the engine. He was endeavouring, at the present time, to get a trial under these conditions, and he hoped, before long, to be able to present it as an accomplished fact, instead of a prospective idea. Whilst upon the subject of adhesion, he would mention, that on an incline of his own construction, he had sometimes seen the train brought to a stand, and on examining the sand-box of the engine, instead of sand he had found in it only stones, and clay: this naturally accounted for the difficulty experienced in working the incline, and he believed, that the difficulties experienced on other inclines, were often due to similar carelessness.

It was also stated, that none of the engines employed in England, would move the loads at the same rate, as those upon the Semmering Incline: but he could not admit, that those engines showed any improvement upon the practice of this country, for the last fifteen years. He believed, that as early

as the year 1845, a peculiarly-powerful engine was working on the Lickey Incline, and he concluded, that it was one of those of which Mr. Kirtley had given an account. Now if it was correct, that 307 tons could be moved up that gradient of 1 in 37, at the rate of 6½ miles an hour, with one large and one small engine, it followed, that one alone would be quite able to haul the 165¼ tons spoken of as the Semmering performance, at an equal speed of 11 miles per hour. One of those engines had been in the habit of drawing up fifty loaded wagons at a time, weighing, perhaps, 250 tons. On the Dainton Incline, lighter trains of 79, or 80 tons, were moved at the rate of 17 miles an hour; the pull of the single engine which did that work, was about 4,600lbs., and the consumption of coke, (taken, as in the other cases, at the average per mile, on the whole line,) was only 24lbs. per mile.

Mr. Hawkshaw, V.P., was anxious to correct a statement, which might have the effect of misleading those who were unacquainted with the railway system of this country. It had been asserted, that the Lickey and the Dainton were the only inclines worthy of notice: but such was not the case. There were a great number of inclines on the English and Scotch lines, and they were increasing every year; for railways were continually in course of construction through hilly districts, which were formerly regarded as impracticable. Even before the construction of the South Devon Line, there were numerous inclines, which were worked with a large passenger traffic. Halifax, for instance had an incline of 1 in 44, and thirteen years ago, twenty-two passenger trains, together with heavy goods trains, were daily, without difficulty, conveyed over it. The change in the views of Engineers on this subject, had been very great. He remembered the time, when a gradient of 1 in 100 was thought to be the utmost that ought to be ventured upon; and

that, with 1 in 50, locomotives must be put aside, and rope must be employed. The incline on the North-Western Railway, from Camden Town to Euston Station, was for a long period, worked by a rope, which was considered the only practicable mode, although the rise did not average more than 1 in 66. The result of experience had been to discard the rope and trust wholly to locomotive power. There was scarcely a portion of railway in England over which more traffic passed, than the incline at Hunt's Bank, on the Lancashire and Yorkshire Line, where the gradients were 1 in 50 and 1 in 49, yet it was daily accomplished without stoppage, or accident. Another incline, also under his charge, where rope traction was, until very recently, employed, was that at the approach to Oldham, a town 8 miles from Manchester, with 120,000 inhabitants: that incline was 1 in 27 for ¾ mile. To avoid it, another line was proposed between Manchester and Oldham, with a gradient of 1 in 60, but the Engineer declined to support even that gradient, unless it were worked with a rope. The result was, that the incline of 1 in 27, was maintained, but, two years ago, it was found, that the rope was of no advantage, and trains now ran up this incline every half-hour, by locomotive power alone. The trains, it was true, were not heavy, generally consisting of six, or seven carriages, and the goods trains, of eight, or nine trucks. He might add, with reference to the inclines in Lancashire and Yorkshire, that the engines were not specially constructed for working them, but the ordinary engines were, generally speaking, quite equal to the duty. It was not necessary to enter into a comparison of the work performed on different inclines, for it was clear, within certain limits, that engines could be made powerful and heavy enough, to take any weight up any incline, and the proper weight and power to be employed must be left to the prudence of the

Engineers. He applied this remark to the opinion which had been expressed, that the weight might be reduced from eight times, to five times the drag of the engine ; but this was not a question of engineering skill, for the degree of adhesion obtained, very much depended upon the state of the weather. A long list could be given of gradients similar to those he had mentioned : at Bradford, and again at Leeds, he had made inclines of 1 in 50. Steep inclines were, therefore, no novelty, in railway engineering, nor were the performances cited, greater than those which had been accomplished for years past, in this country.

Captain W. S. Moorsom explained, that in speaking of the Lickey and Dainton Inclines as the only ones worth mentioning, he did not mean to imply, that there were no others on which a large traffic was worked, (although fifteen years ago, there were, comparatively speaking, no large traffics); but he meant that those inclines were, and still remained, almost the only ones which presented any very heavy gradients, and which, being situated in the middle of the course of the lines, had to be worked on different conditions to the terminal inclines at Oldham, Halifax, &c.

As to the question of priority, he believed, that anterior to the working of the Lickey Incline, in 1839-40, there was no other of any importance, on which locomotives conveying trains, freely ascended. He claimed no scientific merit for the suggestion of reducing the weight to five times the power of the engine : but he could not admit, that adhesion was a question of weather. Whatever might be the state of the weather, and the state of the rails, the above proportion was, in his opinion, quite sufficient to enable the engine to work up an incline.

Mr. Hawkshaw, V.P., observed, that the Hunt's Bank and Halifax Inclines were originally terminal inclines, although they were now no longer so. But he did not consider that fact very material, for it did not affect the power which the engine was called upon to exert.

Mr. Vignoles said, he was among the first to advocate the adoption of steeper gradients. Being well acquainted with the Semmering Incline, he would call attention to the sharp curves on that line, of not more than 10 chains radius, with a gradient of only 1 in 42, which must materially influence the working of the engines, at even a moderate speed, and require an increase of power. But the most important question for consideration, and upon which he had stated his opinion to the Austrian Government, was, whether such heavy engines as those of the Engerth construction, could be worked as conveniently and economically as a number of smaller engines coupled together, or disposed in different parts of the train. He was convinced, that the latter system, which was the one adopted in England, and on the Giovi Incline in Piedmont, was preferable to the Austrian plan, both in point of convenience, economy, and regularity. It was now about twelve years ago, that a steep gradient was adopted in Bavaria, and this was the first introduction of such inclines on the Continent : in that instance, the curves were easier than those on the Semmering, but the gradient was 1 in 40, which, he conceived, could be easily worked by locomotive power. As far back as 1833, he continually ran up the St. Helen's Incline, which was then 1 in 30, with an engine and carriages, without having the rope attached.

With reference to adhesion, from the experiments he had made, he had come to the conclusion, that it could not be depended upon in all states of the weather, at more than one-

fifteenth of the weight; and he had found, that the adhesive power decreased in the ratio of the sine of the angle of inclination of the plane.

NOTES ON VARIOUS OTHER RAILWAYS WITH STEEP GRADIENTS AND SHARP CURVES.

GUAGE 4 FEET 8½ INCHES.

THE METROPOLITAN AND GREAT NORTHERN RAILWAYS, are joined by a curve of 7½ chains radius on a gradient of 1 in 46 in a Tunnel.

THE NAVIGATION INCLINE ON THE TAFF VALE RAILWAY, is half a mile in length and has an average gradient of 1 in 20 and is worked by a locomotive power.

THE VALE OF NEATH RAILWAY (GLYN NEATH INCLINE) has a gradient of 1 in 47 and is worked by locomotive power.

* THE NEATH AND BRECON RAILWAY commences by a junction with the Mid-Wales, and Brecon, and Merthyr Railways at Brecon, and after passing up the valley of the Usk for about 9 miles, turns to the Southwards, and crosses over the Northern lip of the Great South Wales coal-field, winding its way through the hills known as the Vans of Brecon at an elevation of 1300ft. above the sea, by means of curves of 15 to 20 chains radius and up gradients of 1 in 50. After passing over this ridge it terminates by junctions with the Vale of Neath and Swansea Railways. The total length of the line is about 32 miles. It was on this line that the first Fairlie Engine was tried.

* The information respecting this line has been obtained from Mr. A. R. Binnie, Executive Engineer C. P., who was one of the resident Engineers during its construction.

* THE MID WALES RAILWAY commences by a junction with the Cambrian Railway at Llanidloes on the River Severn and after passing over the low watershed between that river and the Wye, passes down the valley of the latter river by Rhayader, and Builth, to the Three Cocks Junction, where it leaves the Wye, and after running a short distance to the South-west ends by a junction with the Brecon and Merthyr Railway at Tall-y-llyn. The total length of the line is about 50 miles, its ruling gradient is 1 in 75 and it has curves of 15 and 20 chains radius. The remarkable works are Iron Pile Bridges with plate-girders, one large lattice-bridge of 200 feet span over the Wye, and three small tunnels.

† THE WHITLAND EXTENSION OF THE PEMBROKE AND TENBY RAILWAY runs from the town of Tenby to Whitland station on the South Wales line a distance of 16 miles viâ the Town of Narbeth, and is chiefly remarkable for its steep gradient ruling 1 in 50, and its sharp curves down to a radius of 12½ chains.

‡ THE BRECON AND MERTHYR RAILWAY. This well known line with its gradient of 6 miles of one in 38, needs little notice further than to say that it is regularly worked by locomotives of the ordinary tank description.

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* The information respecting this line has been obtained from Mr. A. R. Binnie, Executive Engineer C. P., who was one of the resident Engineers during its construction.

† This extension of the Pembroke and Tenby Railway was laid out by Mr. A. R. Binnie, Executive Engineer C. P., under James Matthias, M. Inst. C. E.

‡ Mr. F. L. O'Callaghan Executive Engineer C. P., was one of the Engineers engaged in laying out this line.

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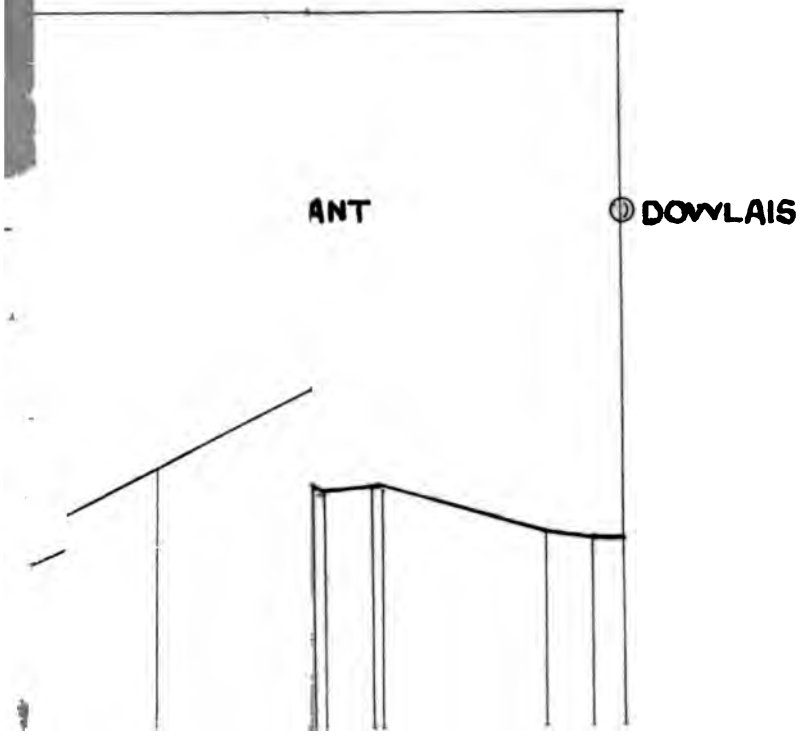

APPENDIX.

EXTRACTS from the Report of the "Royal Commissioners on Railways"

1867.

Para 54, *Pages* 27 *and* 28.

Whatever may have been the contradictions of the course of legislation which has thus been pursued, it cannot be doubted that it has led to a very rapid development of the railway system, and consequently of the national resources, probably far more rapid than could have taken place under any other conditions, and has induced improvements in the construction and working of the railways which, without the spirit of emulation engendered by it, must have taken years to attain. Thus whilst in France there is less than 1¼ miles of railway, in England and Scotland there are 2½ miles of railway, to 5,000 inhabitants.

Under these conditions the railway enterprize of the country at the end of 1865 had raised by shares and loans 456,421,840*l.* and had opened 13,289 miles of railway. These railways had carried during the year (exclusive of 97,147 season-ticket holders) 251,862,715 passengers, for the conveyanee of whom 16,572,051*l.* had been received. The railway

Companies had received during the same year 19,318,062*l.* for the conveyance of live stock, minerals, and merchandise, or a total of 35,890,113*l.* The working expenses amounted to about 17,200,000*l.*, leaving a profit of nearly 18,700,000*l.*, equivalent to 4·1 per cent. upon the money paid up.

The amount of capital which railway companies were authorized to raise by shares and loans down to the end of 1865 was 578,425,763*l.*

During last session 203 Acts were passed, which authorized 47,407,832*l.* to be raised by shares and loans, and 1,063 miles of railway to be constructed; but these are not included in the foregoing summary; hence the entire railway capital sanctioned by Parliament amounts to 625,833,595*l.*, being 169,411,755*l.* beyond the sum expended to the end of 1865.

A deduction must be made from this on account of undertakings which have been abandoned or cannot be carried out, but we are unable to state to what extent.

Para 122, *pages* 54 *and* 55.

The average gross receipts per train mile will give a rough idea of the general accommodation afforded; as, supposing the charges not to be materially different, the higher these receipts are, the fewer will be the number of trains in proportion to the amount of traffic carried; and *vice versa.*

These receipts we find as follow:—

	s.	*d.*
In Great Britain the Board of Trade returns for 1865 give...	5	1·74
For 1864	5	3·22

For France we possess no statistical returns to enable us to calculate the average over the whole kingdom, but from the periodical reports of some of the principal companies, and

from information specially furnished to us, we arrive at the following :—

Lyons and Mediterranean (Appendix DB.) ..	10	2
Nord	7	4
Orleans	8	5
Ouest	7	11
Est	5	10
For Belgium the "compte rendu des operations" on the railways of the state for 1864, gives	6	3
For Prussia the "statistische Nachrichten" for 1864, give, on the whole of the railways of the country...	5	9
For Austria a return of some few years old gives for the State railways in that country...	5	4

Many other German returns which we have do not appear to make the train milege an element in their data.

It will thus be seen that in every case the foreign average receipts per train mile are larger than in Great Britain, in some cases very much larger.

Para 123, *page* 55.

But in order to compare the accommodation more directly, we have extracted from various foreign official time tables the data given in Appendices DM. and DN. These documents show in a perspicuous from the particulars of the railway service in several parts of the continent, and its comparison with the service of a corresponding nature in this country. The latter is also shown in a different form in Appendix EE.

Number of Trains.—As regards France, the statements show that in almost every instance, where any comparison can be drawn, the number of trains for first and second class passengers is much greater in this country than in France.

For example—

——	First-class Trains, daily.	Second-class Trains, daily.
From Pairs to three large naval arsenals there are ...	8	4
From London to three large naval arsenals there are ...	32	22
From Pairs to six commercial sea-ports there are ...	32	21
From London to six commercial sea-ports there are ...	61	56
From Pairs to seven suburban districts there are ..	141	141
From London to seven suburban distsicts there are ...	266	266
From Pairs to three large provincial towns there are ...	23	16
From London to three large provincial towns there are...	51	51
From Pairs to 10 smaller provincial towns there are ...	66	40
From London to 10 smaller provincial towns there are ...	101	83

Para 124, *Page* 56.

Many other examples of actual English fares will be found in Appendices DM. and EE.; and various particulars on this head are also given in the returns to Inquiry No. 5, furnished by the various railway companies, and published in the Appendix.

A few examples from these returns will illustrate the practice of some of the larger companies in regard to their passenger fares.

AVERAGE SINGLE FARES per mile :—

——	Express.		Ordinary.		
	1st Class.	2nd Class.	1st Class.	2nd Class.	3rd Class.
	d.	*d.*	*d.*	*d.*	*d.*
Great Northern	No Express.		2·00	1·45	...
Lancashire and Yorkshire ...	Do.		1·95	1·48	0·84
Midland	Do.		2·22	1·61	...
North-Eastern	Do.		2·10	1·50	0·85
South-Eastern	2·51	1·85	2·05	1·46	0·87

Para 127, *pages* 58 *and* 59.

The speeds of trains in Great Britain and on the continent are shown in a large number of examples in Appendices DM. and DN.

	Miles per Hour.
In England the express trains run generally, including stoppages, about	40
From London to Newcastle the quickest train run...	40
„ „ Liverpool	37
„ „ Bristol	42
„ „ Southampton	34
„ „ Peterborough	47
„ „ Brimingham...	38
„ „ Brighton	46
The average of all the English examples of the quickest trains in Appendix DM., omitting the suburban, gives	36½
The ordinary trains in England run generally, including stoppages, about	18 to 30
The average of all the English examples of tne slowest trains in Appendix DM. gives...	19½
In France the express trains run, including stoppages	25 to 35
The quickest in Appendix DM. is, from Paris to Rouen	36
The average of the quickest examples, omitting suburban, is...	31
The ordinary trains run from	16 to 25
The average of all the slowest trains in Appendix DM. is	18
In Belgium the quickest trains run from ...	29 to 35
„ the slowest	18 to 23

	Miles per Hour.
In Prussia the quickest	29
„ the slowest	17 to 21
In Austria the quickest	20 to 29
„ the slowest	14 to 21
In Bavaria and along the Rhine the quickest...	24 to 32
„ the slowest	13 to 24
In Italy the quickest	24 to 30
„ the slowest	15 to 24

Para 141, *page* 65.

In considering the improvement of goods traffic, it is very difficult to institute any comparison with the past, because the introduction of the railway system has entirely altered all the conditions of that traffic, and has enabled industry and trade to spring up which, without railways, could have had no existence.

From the evidence which we have received, we will, however, cite some of the charges formerly made, and compare them with present rates.

BRISTOL TO LONDON. RATES PER TON.

Articles.	Rates charged by Carriers.						Rates charged by Railway.	
	1820.		1830.		1840.		1866.	
	s.	*d.*	*s.*	*d.*	*s.*	*d.*	*s.*	*d.*
Drapery ...	66	0	60	6	47	6	40	0
Hops ...	68	0	63	0	49	6	40	0
Oil ...	60	6	47	0	42	0	20	0
Tabacco ...	66	0	66	0	47	6	26	8

BIRMINGHAM TO LONDON. RATES PER TON.

Articles.	Canal.				Railway.	
	1836.		1842.		1866.	
	s.	d.	s.	d.	s.	d.
Undamageable iron	25	0	...	...	15	0
Hardware	60	0	40	0	27	6
Sugar	40	0	37	6	21	8
Tallow	35	0	30	0	21	8
Drapery	70	0	45	0	40	0
Glass	70	0	...	...	27	6

From Manchester to London bales and grain were carried by quick vans in 1833 at 20*l.* a ton; in 1834, by canal, at 4*l.* a ton; in 1840, by railway, before the railway companies were carriers, at 3*l.* 4*s.* 8*d.* a ton; and in 1866 at 1*l.* 15*s.* per ton. On the other hand, grain carried between South Staffordshire and Liverpool in 1831 cost, by canal, 13*s.* 4*d.* per ton, and is charged in 1866 from 10*s.* to 12*s.* 6*d.*

Para 147, *pages* 70 *and* 71.

Having thus endeavoured to explain the various questions which affect the goods traffic of the country and influence the rates at which it is carried, we will proceed to consider the actual charges made, and compare them with those made on foreign lines.

But in comparing the mileage rate at which goods are conveyed between different places it is necessary to estimate the terminal charge, otherwise the rate per mile of short distance traffic appears not only high, but singularly unequal in cases apparently similar. Many of the complaints against railway companies appear to have arisen from not sufficiently appreciating those considerations.

The following table will give an example of the maximum rates authorized by the Acts of the several companies named*:—

General Description of Articles.	London and South-western.	Great Eastern.	Great Western.	Great Northern.	London and North-western.	Midland.
	d.	*d.* *d.*	*d.* *d.*	*d.* *d.*	*d.* *d.*	*d.* *d.*
Dung, Lime, bricks, coal, pig iron, iron ore	2	1½ to 1½	0⅞ to 2	0¾ to 1¾	0⅞ to 1½	1 to 2
Sugar, corn, earthenware, timber, iron castings, sheet and wrought iron, damageable iron	3	2 to 2½	2 to 3	1¾ to 2½	1½ to 2½	2 to 2½
Cotton and other wools, drugs, manufactured goods ...	3	2 to 2½	2½ to 4	2½ to 3	2½ to 3	3 to 4
Fish, feathers, household furniture, clothing, silk ...	5	4*d.*	3 to 4	3 to 3½	3 to 3½	3 to 4

It will be found that in practice the charges are very much lower than these, especially in the case of coal and mineral traffic.

The table in Appendix EG. gives a great number of examples, extracted from the evidence we have received, of actual charges made for the railwavs carriage of goods of different kinds between various places. It will show the great differences which exist in the charges made, as well as the effect of eliminating the terminal charge adopted by the Clearing House, on which we have already remarked.

* The rates quoted are those given in the principal Acts of the companies; the minor Acts for branches and subordinate lines frequently authorize rates differing materially from them.

The following few instances, selected from the table, will illustrate these differences.

Commodity.	From and To	Gross Charge per Ton per mile,	Rate per Ton per Mile after deducting Terminal charges
		d.	*d.*
Timber and deals	Liverpool to Saddleworth	3·41	2·59
,, ,,	Newport to Wolverhampton	0·52	0·33
Chemicals	Liverpool to Bradford	2·57	1·20
,,	Newcastle-on-Tyne to Hull	0·73	—
Sugar	Nottingham to London	3·81	2·62
,,	Glasgow to Manchester	0·89	0·46
Grain	Liverpool to Bolton	3·57	2·29
,,	Newcastle-on-Tyne to Lincoln	0·54	0·35
Bar iron	Wolverhampton to Birmingham	3·85	1·09
,,	Wolverhampton to Swansea	0·65	0·37
Pig iron	Wolverhampton to Birmingham	2·61	1·23
,,	Wolverhampton to Swansea	0·65	0·44
Hardware	Sheffield to Wolverhampton	3·45	2·34
,,	London to Aberdeen	0·87	0·60
Nails	Wolverhampton to London	2·44	1·22
,,	Liverpool to Newport, Mon.	0·89	0·67
Earthenware	Potteries to London	2·40	1·40
,,	Newcastle-on-Tyne to London	1·02	0·47
Encaustic tiles	Stoke to Congleton	7·50	2·00
,,	Stoke to Hull	1·64	0·99
Machinery	Blackburn to Rochdale	8·33	6·33
,,	Liverpool to Hull	1·94	1·40
Lead (sheet and pipe)	Derby to Manton	4·71	4·00
,, ,,	Birmingham to Manton	2·26	1·87
Silk	Derby to Coventry	8·94	6·89
,,	Derby to Glasgow	4·36	4·01
Ale	Burton to Tallington	4·29	2·91
,,	Burton to Aberdeen	0·85	0·64

The differences in the rates warrant the conclusion that the charges are low when competition exists in the means of conveyance, or

when the article has to compete with a similar article brought from another place to the same market.

Appendix ED. shows some of the rates charged on French railways compared with rates for similar distances in England; it is formed from the book of rates on French railways for the year 1865.

This table shows that there are very considerable differences between the French and English rates for the same goods carried over corresponding distances; in some cases the former being the higher, in others the latter. Taking, however, the average of the whole, we find the following results:—

——	English Rate per Ton per Mile, Station to Station.	French Rate per Ton per Mile, Station to Station.
	d.	*d.*
For the goods comprised in Class 1 of the Franch classification (being the more valuable class). ...	3·37	2·60
For Class 2	1·66	2·29
For Class 3	1·31	1·67
For Class 4	1·07	1·28
For Class 5, one article only ...	1·07	0·96

So that for the great bulk of goods traffic the English rates are considerably lower than the French.

Rates on Belgian Railways.—On the Belgian Government railways there are four classes—

	d.		*d.*
First class ...	1 · 70	Third class ...	0 · 89
Second claas ...	1 · 16	Fourth class ...	0 · 62

This is in addition to a uniform charge of 1*s.* 1*d.* per ton in all classes; also for loading and unloading 10*d.* per ton; and if collected

and delivered about 2*s.* 6*d.* per ton. Coals which are in the fourth class are, it is stated by M. Fassiaux, carried specially for transit and export at ·32*d.* per ton per mile, and occasionally at ¼*d.* per ton per mile, including waggons.

Rates on German Railways.—On the German railways there appear to be many varieties of classification and rates, some at quick speeds (Eilgut) and some at slow speeds; but it will be sufficient to take the general results given in the report of M. Dubosq to the French Government in 1863, according to which there are three classes of goods—

—	First Class.	Second Class.	Third Class.
	d.	*d.*	*d.*
Baden	2·2	1·7	1·4
Bavaria	3·4	2·0	1·1
Austria	3·6	2·6	1·7
Prussia	2·3	1·7	1·2

On these lines special agreements are allowed to be made, provided all persons sending similar quantities for equal distances are treated alike; and under these coal is carried in Westphalia and Silesia at ·46*d.* per ton per mile. including supply of waggons, and in Austria at 1 · 1*d.* per ton per mile. No raising of rates is permitted until after six weeks' notice.

In Germany the loading and unloading are included in the rate per mile for the first and second classes, and the third class of goods is generally loaded and unloaded by the consignor and consignee.

Para 154 *pages* 73, 74 *and* 75.

5.—Certain Conditions affecting Economy of Working.

In order to determine whether more economical arrangements can be made for the working of railways, so as to make any considerable reduction in the costs of conveyance and in the charges to the public

on account thoreof, it is necessary to advert to the chief sources of expenditure of railway companies, as well as to the amount of work which they obtain out of their rolloing stock.

The following shows the proportion which the different items of expenditnre in the working of railways bore to each other in 1842 and 1865 on an average of all the railways of the United Kingdom.

——	Per-centage Proportion	
	1842.	1865.
Maintenance of way	17·8	18·31
Locomotive charges	30·	27·48
Repairs of carriages	31·3	8·83
Traffic charges		28·64
Rates and taxes	5·9	3·93
Government duty	10·	2·63
Compensation for injury to passengers	5·	1·94
Ditto goods		0·68
Legal and parliamentary expenses		1·44
Miscellaneoos expenditure		6·12
	100·0	100·00

The reports of the Board of Trade show the following cost per train mile for 1840 :—

	d.
Cost of coke per mile	8·356
Ditto oil	0·360
Ditto wages of Enginemen and Firemen ..	1·510
Ditto wages of Labourers and Cleaners, &c. ..	1·910
Ditto Superintendent, Clerks, Office Charges, Firemen	2·040
Ditto repairs	3·549
Ditto sundries	0·936
	18·661

The whole cost of working a train on the Graet Western Railway for 1865 amounts to 2*s.* 7·81*d.* per train mile; on the Great Northern Railway to 2*s.* 6·685*d.*; on the South-eastern Railway the expense is 2*s.* 10·72*d.*; and on the Northern of France 2*s.* 7·34*d.*

Para 155 *page* 76.

The following are the average receipts per train mile, from all sources of traffic, on 12 of the most important English railways, as deduced from the Board of Trade returns for the year 1865 :—

	s.	d.		s.	d.
Great Eastern ...	5	4·07	Midland	4	9·68
Great Northern ...	4	10·25	North-eastern ...	4	3·12
Great Western ...	5	5·05	South-eastern ...	5	10·36
Lancashire and Yorkshire	5	9·39			
London and North-western... ...	6	0·80	Average of England...	5	3·23
London and South-western... ...	5	2·14	„ Scotland...	4	6·48
London, Brighton and South Coast ...	5	1·71	„ Ireland ...	4	7·80
London, Chatham and Dover	4	10·65	Average of the United Kingdom ...	5	1·74
Manchester, Sheffield, and Lincolnshire ...	5	6·83			

EXTRACT from the Report to the Lords of the Committee of Privy Council for Trade and Foreign Plantations on the Railways of the United States by Captain Douglas Galton R. E. 1857.

Pages 11 *to* 23.

CONSTRUCTION.

Construction of Road.

The character of American railways, so different in its prominent features from that of railways in this country, is the result of the want which they have been called upon to supply. A means of communication was required which could be laid cheaply and rapidly through forests and uncultivated districts where high speed was of far less consequence than certainty of communication. A railway was the instrument best adapted to supply this want, and it would afford a better means of communication at a less cost of maintenance than an ordinary road.

As the first cost of a railway was a more important consideration than the after expense of working the line when made, sharp curves and steep gradients were unhesitatingly adopted, and the railways were opened with a minimum of accommodation. The Baltimore and Ohio Railway affords a striking illustration of a line opened with steep gradients, which have since been improved. In order to avoid for a time an expensive tunnel, which has since been constructed, the line was carried by a series of zigzags, ascending over a hill by a gradient of 1 in 18 at its steepest part. Each zigzag terminated in a short level space, so that the train was run up one zigzag on to this level space, and then backed up the next zigzag, and so on. The load which could ascend in this case was of coursr very small. There are curves on this railway of 360 feet radius, and curves of 400 feet radius are common; the railway follows the sinuosities of the valleys in its passage across the Alleghany Mountains: it is also carried through the streets at Baltimore down to the wharves, and passes round right angles. In these streets the traction is by horse power.

The embankments and cuttings of a railway at its opening are generally completed; the bridges are ordinarily of timber, which, not being always well seasoned, is often a cause of considerable expense. The designs of many of the bridges for large spans, and also of the roofs of stations in which timber alone, or timber in connexion with iron is used, exhibit great engineering skill, and are very instructive. The railway bridge of largest span is the suspension bridge over the Niagara river, connecting the United States with Canada. The span of the bridge is 800 feet; and the level of the rails is 250 feet above the water. The particulars of this bridge have been already published in this country. On many railways, iron and stone are being adopted to replace timber structures which have decayed. I have appended a sketch of one iron and one wooden bridge of recent construction, which well deserve consideration.

The ballasting is generally very deficient at first. On the prairie lines it is impossible to procure ballast except from very considerable distances. In constructing these lines a ditch is dug on each side of the road, and the soil banked up so as to cover the centre of the sleepers, but sloped off on each side, leaving the ends of the sleepers exposed, in order to allow rain to drain off rapidly.

The elasticity of the soil makes these roads far from disagreeable to travel over when dry; but in wet weather and frost the absence of balast is a source of great inconvenience and danger. This may be remedied, to some extent, by placing a good drain under the centre, as well as at the sides of the roads; but nothing can compensate for the absence of ballast which, in a severe climate like that of America, should be of broken stone, not less than two feet in depth under the sleepers, with good drainage; it is sometimes customary to slope the top of the ballast on each side, so as to cause the snow melted on the surface to drain off.

The gauge of American railways varies: the general gauge in the United States is 4 feet 8½ inches; the gauge of the Ohio railways is nominally 4 feet 10 inches, but it is in many cases in practice made 4 feet 8½ inches. The New York and Erie, and one or two lines in connexion with it, have a 6 feet gauge. The gauge of Canadian railways is 5 feet 3 inches. The break of gauge is of less consequence than in this country, because there is not so much interchange of working stock between the several railway companies.

The sleepers on American railways are usually of oak, cedar, or hemlock spruce, of about 6 inches by 8 inches scantling, and from 7 feet to 9 feet long.

In consequence of iron being taxed to the amount of 30 per cent., the American railway companies have been obliged to economize iron to the utmost. The rails are made as light as possible, the usual form being the contractors' rail of from 50 to 65 lbs. weight. Many railway companies obtained rails from England, for which they paid by mortgage bonds. The rails thus obtained have not, it is stated, generally proved durable. With regard to rails obtained from American iron works, the plan is frequently adopted of contracting that the rails shall last a specified time, the failure of any rail being made good, together with expenses incurred in consequence. The rails are spiked to sleepers laid transversely, the joint being generally secured by means of a chair made of boiler-plate, with a lip cut out on each side and turned up; the lip is barely 3 inches broad, and projects about 1½ inches on each side of the joint. It is stated that the lip soon works up, and when hammered down is apt to break off; consequently the joints on a road of this description soon become very bad; and several plans have been tried to improve them.

On the New York and Erie Railway, in some places eleven sleepers have been placed under on 18-feet rail.

On some lines I saw a wrought-iron chair 14 inches in length, made to slide on to the rail without any keys.

Several forms of compound rails, for avoiding joints, have been tried, but I was informed that they have invariably failed.

The ordinary fished joint had been tried, but the necessity for economizing iron, and of preserving a sufficient breadth of base, has so limitted the depth and modified the form of the rail that it is not generally well adopted to this mode of fastening; and it was stated not to have proved successful. A modification of the fished joint, in which a piece of iron about 12 inches long is used on the inside of the rail, and a piece of oak 5 feet long on the outside, has been tried on the Baltimore and Ohio and other railways, and appeared to answer.

The switches and points in use upon English railways are almost unknown in America, shifting rails or contractors' points being universally used in lieu; and consequently, if the points are set wrong, the vehicles which pass through them must leave the rails. The result of this is that the points are almost always kept locked, and a signal is invariably attached to them.

On the Newhaven Railway, in order to render it impossibl for the switches ever to be set except for the main line, they are worked from inside a box, the lever of the switches being connected with the door of the box, so as to shut it when they are held open for the siding; thus the pointsman cannot get out of his box unless the points are set right for the main line.

The signal arrangements at stations, and even at junctions, are generally very imperfect.

Level crossings are scarcely ever provided with gates or gate-keepers, except in special cases near towns; but a large board is placed over the crossing with the words printed on it in large letters :—"*Railroad crossing. Look out for the cars when the engine bell rings.*" On the Philadelphia and Reading Railway, a blue coloured light is shown at all level crossings at night.

It is the invariable duty of the engine-driver to ring a large bell, placed on his engine, whenever he approchase a level crossing or passes along a street.

Cattle-guards are constructed on each side of every level crossing, in order to prevent cattle and animals from straying on to the line. These are trenches about 4 feet deep and 4 feet 6 inches broad, cut across the railway, the rails being supported by narrow balks laid across the opening. Laths, a few inches apart, are laid across the opening to enable persons to pass over.

The railways are generaly well fenced, except at stations or where the railway is carried along roads or streets, in which case no separation is made. The main line of the Baltimore and Ohio Railway runs through the streets at Baltimore to the passenger station; the trains are drawn by locomotives, and a man on horseback rides along in front of every train, blowing a trumpet, to warn people to keep off the track.

A very general practice prevails of distributing the goods traffic by means of rails laid along the streets to wharves and private establishments, along which the railway cars are moved by horse power. At some seaport towns in this country, as, for instance, Aberdeen, Dundee, and Birkenhead, rails are carried on to the wharves, but not to the same extent as in America. The practice is, however, one which might be adopted in many places in this country with great advantage, and with saving of expense in unloading and reloading. The construction of the cars in America enables them to be moved round very sharp curves.

The stations are generally unfenced, and passengers stations are considered public throughfares. The accommodation is generally inadequate and very indifferent, there being a great want of waiting-rooms and other conveniences, as well as of means of obtaining information. At some stations, however, where the passenger traffic is large, the booking-office has a second opening into the ladies' waiting-room, so that ladies travelling alone can obtain tickets without crowd or difficulty. This arrangement is one which might be adopted with great advantage in this country.

Construction of Rolling Stock.

The practice of contructing the railways in a hasty and imperfect manner has led to the adoption of a form of rolling stock capable of adapting itself to the inequalities of the road; it is also constructed on the principle of diminishing the amount of useless weight carried in a train.

This principle is, that the body of the car or waggon is carried by two four-wheeled trucks, one at each end. The body is attached to these trucks by means of a pintle in the centre, the weight resting on small rollers at each side. The main framing of the truck is supported on springs resting on the axles, and the pintle and rollers are fixed to a cross-beam, which is attached by springs to the main framing; so that between the body of the car and the axles are a double set of springs. India-rubber springs are in general use, but they aften become hard; consequently sometimes steel springs are used, with great advantage. Any side movement which might result from the slight play allowed to the cross-beam is counteracted by springs placed between its ends and the framing. An iron hoop attached to the framing passes under the axle on each side, so as to support the axle in case it should break.

The bearings do not differ materially from those used in England. But the axle box is formed so as to allow of oil being used as a lubricator, as it is well adapted to withstand heat and cold. The oil is contained in the lower part of the axle box, cotton waste being pressed in to prevent it from shaking about, as well as to keep it in contact with the axle; the front is screwed on, and, at the back, a leather fits close

round the ax e, and prevents the admission of dust. It is stated that under favourable circumstances this kind of box will run sometimes for a month without requiring to be touched, but there is great difficulty in obtaining good oil.

The wheels used on American railways are of cast iron, with chilled tires. The wheels are from 30 to 36 inches in diameter, made without spokes. These wheels, when made by the best marks, will run from 60,000 to 80,000 miles before the tires are worn, and they are said not to be liable to break; they weiget rather more than 500 lbs., and cost from 3*l.* to 3*l.* 10*s.* each; they are not of course so true as turned wheels, but their first cost is less; they wear well, and during the time they last they require no expenditure for turning up; any crack can be more easily detected by sounding with a hammer, and when a wheel breaks it does not always do the mischief that is done by a broken tire. Chilled cast-iron tires are used on some of the railways for the driving wheels of engines; they are made 3 inches to 3½ inches thick, and 6 inches broad, and cylindrical; they are bored out to a true cone to fit the centre, which is also of cast iron, turned to a similar cone, and secured in place by screws. These chilled castings are stated to be preferable to steel, or to wrought iron, on account of their being less liable to fracture in frost.

The iron, of which they are made, is of a very superior quality, and great practical skill is necessary in the operation. It is stated that there are only three firms in the United States whose wheels are fully to be relied upon.

The only connexion between adjacent cars is at the centre, by means of the draw-bar; the draw-bar terminates at each end in what is termed a bumper, which enables it to act as a buffer, as well as a means of connexion. In the most approved construction of car the draw-bar is continuous under the car, and is attached to elliptic springs, which act in both directions.

No force is necessary in coupling the cars, as the ends of the draw-bar or bumpers, abut against each other; a shakle is introduced

through the opening behind, and two pins are passed through the eyes; about an inch play being all that is allowed. An iron shackle is generally used; but on some railways the shackle is made of oak 18 inches long, 2 inches thick, 6 inches broad, with holes for the pins 1½ inch × 2 inch, at a central distance apart of 12 inches. The block, as well as each hole, is bound with iron; but the iron band round the block is divided on each side at the centre, so that if a car leaves the rails the said wrench would break the shackle transversely.

In coupling passenger cars the man stands on the platform at the end of the car; but in freight cars, when there is no platform, the following self-acting contrivance for dropping in the pin, is sometimes adopted to prevent injury to the man employed. When two cars are to be coupled, the pin in the bumper of one of the cars is supported by means of a ball, and the shackle is fixed by its pin in the bumper of the other car; when the cars are moved one against the other, the shackle in one bumper pushes back the ball in the other, and allows the pin to drop into the hole.

All possenger cars, and almost all freight cars, are supplied with breaks, which are applied to all the wheels, worked from either end of the car. The blocks of the breaks are lined with plates of cast iron; and it is never intended that the wheels should be completely skidded.

On the Philadelphia and Reading Railway there is an arrangement by which a sudden check in the speed of the engine applies breaks to the wheels of all the cars.

Passenger and emigrant cars, covered freight cars, or low-sided and platform cars for timber and minerals, &c., are placed upon the trucks I have described. Upon some railwoys coal and ballast waggons are used, constructed in the some manner as those upon English railways.

The bodies of the passenger cars are from 30 to 45, and even 60, feet in length. This length renders it necessary that the sides should be supported by a truss, either in the framing or by iron trussing rods below. On lines of 4 feet 8½ inch gauge the cars are about 9 feet, and

on the New York and Erie, 10 feet wide, and from 6 feet to 7 feet 6 inches high. There are two classes of passenger cars, of which one is limited to the conveyance of emigrants. In the centre of each end of the cars is a door, conducting to a small platform, about 2 feet 6 inches wide, from which steps descend on either side to the ground. There is a railing to the platform; with an opening to allow passengers to pass from the platform of one car to that of another, and thus through the whole train.

On many railways this free passage is not allowed to passengers, but the foremost door of each car is locked, so that all passengers must enter at the rear door, and the conductor or servants of the train alone pass through with keys.

The interior of the car forms a large room, with a passage, of from 1 foot 9 inches to 2 feet wide, down the centre, upon each side of which cross seats are arranged. These seats are intended for two passengers each; they are from 3 feet 3 inches to 3 feet 6 inches long, about 1 foot 6 inches wide; and 1 foot apart. The back is arranged to be turned, so that the passenger may sit with his face in either direction. The seats and backs are comfortably cushioned, and there is a window, and ventilator above, to each. A capacious netting is carried along each side, from one end to the other, for the reception of umbrellas, bags, and cloaks. In winter the cars are warmed by means of an iron stove in the centre; and they are lighted at night by lamps placed at the sides.

In a certain proportion of the passenger cars, a portion, about 7 feet long, 3 feet 6 inches wide, is partitioned off, in which is a small room for the convenience of ladies nursing, and a watercloset. In the summer iced-water is placed in water-coolers in the cars.

On some railways, where the journey occupies a considerable time, as for instance, the Illinois Central between Cairo and Dubuque, some of the cars are fitted with compartmeets about the sixe of our first-class carriage compartments, in which the seats are arranged for the backs to turn up, and so to form two tiers of berth, or sofas, for the accommodation of passengers who may wish to lie down. For these an extra price is charged.

The dust caused by the friable nature of the soil is the great inconvenience of summer travelling in the United States.

Several plans have been tried to avoid it. On some railways windows have been constructed, so that the sides should slant out wards and throw it off.

On the Michigan Central Railway a screen of tarred canvas is fixed so as to reach from the lower framing of the cars to within about 2 inches of the rails outside the wheels. The screen terminates in a framework, which is arranged to abut against a similar framework on the next car, so that from one end of the train to the other a tunnel is formed under the cars, in which the dust is confined, and can only escape at the end of the train. This plan prevents dust in the cars, but is said to cause heated axles.

On the New York and Erie Railway, the following plan secures freedom from dust and good ventilation. A funnel placed at the top of the car, faces the direction in which the train is proceeding, and the movement of the train causes the air to pass down this funnel into a chamber, where it is purified. A cistern of water is fixed under the car, and a pump worked by the rotation of the axles of the car forces the water into the chamber through jets arranged to fill the chamber with spary. The air, in passing through this spary, is freed from dust. In cold weather a stove is placed so as to warm the water. The air then passes through flues under the floor into the interior of the car. The windows must be kept closed. As this arrangement is in practical use on several cars on the New York and Erie Railway, it would be well worthy of a trial upon English railways; especially in large saloon carriages.

A baggage car, or a compartment of a passenger car reserved for baggage, is invariably placed next to the engine. The baggage cars are furnished with doors at the sides to facilitate the loading and unloading of baggage. Baggage cars are generally thirty feet long. Next to the baggage cars in the trains are placed the cars with the compartment for mails, or for the Express Companies, who undertake the parcels traffic.

Freight and cattle cars are usually covered. Their ordinary length is twenty-eight or thirty feet, and they are more strongly built than passenger cars.

Almost every car is provided with a break, which can be applied to all the wheels of the car. It is worked from either end, so that one man can work the breaks of two cars. In freight trains the guards usually pass along over the tops of the cars: the small number of bridges and tunnels rendering this course safer than it would be in England.

In every train a simple and perfectly effectual communication between the guard and engine driver is provided by means of a cord. In passenger trains a cord, with swivel-hooks at each end, is provided to each car. It passes through rings in the ceiling, and it is the duty of the conductor to see that the communication between adjacent cars is complete before a train starts. In freight trains the cord is passed over the tops of the cars. This cord is attached to a bell on the engine.

The construction of a train on American railways favours this mode of communication more than on English railways. The carriages are longer, and therefore there are fewer of them, and consequently fewer connexions to be made; and these connexions are between rigid draw bars, without expansion or contraction of buffer springs; and as a person can walk from one end of a train to another, these connexions are made very easily, and any omission is immediately detected.

From above account it will be seen that the rolling stock on American railways differs considerably from that in use in England.

In designing their rolling stock, the Americans appear to have taken their ideas more from a ship than from an ordinary carriage, and to have adopted the from best calculated to accommodate large masses with a minimum of outlay for first cost, as well as the one which involves a minimum of attendance upon the passengers in getting in and out of trains. Whilst the cars have been designed with a view to avoid every appearance of privilege or exclusiveness, or of superiority of one

traveller over another, they have been constructed so as to secure to every traveller substantial comfort and even privacy.

There is only one class, but as the cars are designed with more regard to comfort than English railway carriages, this class is very much superior to second and third class carriages, and only inferior to the *best* first-class English carriages. It is much to be regreatted that almost all English railway companies have so entirely disregarded the comfort of second and third class passengers, although, as a general rule, second-class and sometimes even third-class passengers pay a higher fare than is required for the much superior acommodation of American railways.

No doubt the American railway cars cannot contain so many passengers as would be contained in a carriage of equal length divided into compartments, but the use of a door at each end, in lieu of several at each side, effects a saving in first cost, as well as in subsequent trouble to the company's servants, and allows the cars to be made wider than they could be with side doors, steps, &c. It is also very convenient for the passengers to be able to move about, especially on a long journey. The absence of compartments facilitates ventilation, warming, and lighting at night. There is an advantage derived from the use of trucks, which deserves consideration viz. : that carriages can be moved easily round curves, and that consequently there is some diminution in the resistance of curves; and the use of double springs renders the motion of the cars very easy on a good road. Indeed, these cars travel without accident over bad roads at velocities, when our carriages would probably leave the line. The small diameter of the wheels possibly increases the friction to some extent.

Vehicles of this description would be very convenient in this country on all omnibus lines, and for second and third class traffic; but it is likely that many English first-class passengers would prefer the privacy of a compartment. The use of this description of vehicle would, however, probably render necessary a reconsideration of the mode of buffing and coupling carriages together, if not the adoption of the *bumper* at the centre. This mode of coupling entails very much less risk upon the companies' servants than the mode in use in this country, and it

prevents the possibility of danger arising from the couplings not being properly screwed up; and the use of a rigid draw-bar through the train would afford an easy means of enabling the engine driver to apply breaks simultaneously to all the wheels of the train. The mode of connecting American cars affords rather more protection than ours against that class of accident in which one carriage is forced through the adjacent one, as in such cases the platforms at each end, amounting to five feet of space, must be crushed before the body of the car is injured.

The main advantage of the American cars is that they convey a larger number of passengers, in proportion to the dead weight, than can be conveyed in the carriages generally used on English railways.

On the Baltimore and Ohio Railway, on account of the sharp curves, the cars are shorter than on many other lines, viz., 40 feet in length; these cars will contain sixty persons, and it was stated that they weigh about seven tons. As a general rule on English narrow gauge railways the same number of second-class passengers would scarcely be accommodated under a weight of ten tons.

The passenger car of the New York and Erie Railway Company, is 60 feet long, and would contain above 80 people.

The freight cars on the Baltimore and Ohio Railway, 28 feet long, with a capacity for a load of 9 tons, weigh 6 tons. On narrow gauge English railway, as a general rule, the weight of the goods waggon is not much less than the weight of load.

Engines.—The American engines are constructed upon principles somewhat analogous to those on which the cars are constructed, with the view of obtaining great stability on roads which present at certain seasons considerable irregularities of surface. The weight rests as nearly as possible upon three points; the fire-box end being supported on the driving-wheels, and the smoke-box end upon a pin which rests in the centre of a small truck. The driving-wheels are generally four in number, coupled together, with from 5 feet to 5 feet 6 inches diameter, and placed at about 1 foot 6 inches apart. The hinder pair of

wheels is furnished with flanges, but the leading driving-wheels are generally without flanges, and are frequently cylindrical.* When great speed is required the wheels are increased to 6 feet diameter,† but it is the almost invariable custom to couple four wheels in all engines.

For working steep inclines, engines with eight wheels coupled are used, the wheels are cylindrical and about 3 feet 6 inches in diameter, the leading and trailing wheels alone have flanges. In attaching the framing to the springs the compensating balance lever is used. Some of these engines weigh 30 tons, the position of the engine driver being on the top of the boiler.

In the ordinary engines the truck is made as light as possible, its wheels being generally from 2 feet 6 inches to 2 feet 9 inches in diameter, and about 1 foot 6 inches apart. These wheels are of chilled cast iron, similar to the car wheels. The drivings-wheels are generally of cast iron in the centre, and the tires are of wrought iron or sometimes, as has been already mentioned, of chilled cast iron, which is stated to be better able to stand frost.

In most engines the cylindrical part of the boiler, instead of butting against the fire-box, is connected with it by an inclined plate, so that there is no right angle at that part.

Notwithstanding that the coal fields of the United States occupy an area of 130,000 square miles, and extent into Pennsylvania, Ohio, Indiana, Illinois, Kentucky, Virginia, and Michigan, until very recently wood was the fuel invariably used on American railways. Wood has, however, risen very much in price lately; and on the prairie lines wood is not to be had, but coal is found in their vicinity; on other lines, which pass through the coal measures, coal is a cheaper fuel, Hence its use is gradually being extended on railways, and it will probably soon entirely supersede wood.

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* Since my return to England I have been informed that a great saving in wear and tear has been effected on an Austrian railway by the use of cylindrical wheels. It is stated that the tires do not wear sharp, they last one-third longer, and that the oscillation of the carriages is much less than with coned tires.

† On the Philadelphia and Reading Railway there is an engine, constructed by Mr. Mulholland, with four 7 feet driving-wheels coupled, 17 inch cylinder, and 30 inch stroke. This engine weighs nearly 28 tons, of which 12 tons rest on the leading truck, the remainder being distributed between the driving wheels.

Several attempts have been made to burn bituminous coal in engins, without coking it. In one, the fresh coal is supplied into the fire-box from below, so as to under-lie the heated fuel; in another, the fire-box is divided into two parts, from each of which a flue, with a damper, leads to the tubes, and there is an opening below the surface of the fuel from one part of the fire-box to the other. The fires are alternately charged with fresh fuel, the damper of the fire most recently charged being closed, to cause the smoke to pass through the other fire. I cannot give any decided opinion as to the satisfactory results of either arrangement. This subject is receiving at the present time great attention in this country, and the economical results which are stated to have been arrived at by Mr. Beattie in some new engines which he has constructed for the London and South-western Railway are very extraordinary.

Anthracite coal is used on the Pennsylvanian railways. A form of fire-box, adopted by Mr. Mulholland on the Philadelphia and Reading Railway is stated to be very successful. It is shallow, with a large grate area; the bars are of cast iron, ¾ inch broad, and with ½ inch spaces between them; and a row of air holes four inches deep by 1½ inches wide, which can be opened and closed at pleasuer extends along the front of the fire-box, just over the bars. There is also an arrangement to admit air to the heated gases near the tube plate. The anthracite coal is spread evenly over the grate bars in a layer nine inches thick. The fire-box is made of iron, as is almost invariably the case in America, the sides being considerably sloped inward to ensure that the steam generated from the water in contract with it shall pass off rapidily, and keep the water in constant contact with the iron.

It may be mentioned that the contract for the supply of boiler plate from the makers is frequently similar to that for rails, viz., that if defects in original manufacture are discovered the plate is to be made good, and all expenditure incurred upon it defrayed.

In those engines in which wood is burned, the chimney is surrounded with an inverted funnel of iron, with a grating at the top to catch and contain the sparks. A door at the bottom of the funnel allows the ashes to be removed when necessary.

American engines are provided with what is termed a "cow-catcher," in lieu of axle guards. It is composed of a series of iron bars uniting in a salient angle, formed to throw to one side any thing that lies on the track. The lower bar is about three inches from the rail, and the upper part terminates at the framework of the truck.

This implement derives its name from having been used to protect the engine from cattle straying on the line, and with a moderate depth of snow it answers all the purposes of a snow plough.

Every engine is furnished with a bell of at least 30 lbs. weight, which is always rung by the driver before the engine is moved forward at a station, and also when approaching level crossings, or moving along streets. The bell gives notice of the approach of the engine without frightening horses, as much as the whistle. The side from which the sound proceeds can be easily distinguished, and in the neighbourhood of towns it is a much less objectionable sound to the inhabitants. The whistle is used on emergencies, and as a signal to apply the breaks, &c.

There is one arrangement connected with the engines in America which mere humanity should cause to be adopted in this country, viz., the protection afforded to the engine-drivers and firemen against the inclemency of the weather. The foot-plate of the engine is covered by a roof supported by glazed sides and a glazed front. The windows are arranged to open readily, and a passage is afforded to the front of the engine. This shed is open at the back towards the tender.

This arrangement makes the engine-drivers and firemen much more comfortable, and enables them to keep a far better look-out than when unprotected.

MANAGEMENT.

In a newly-opened country, where the traffic is not sufficient to require more than one or two trains each way daily, and where the stations are far apart, considerable time is allowed for the journey, and a train is not stopped at a station unless there are passengers to take up or set down, or there is freight to be left or taken on.

Under such circumstances, the station service may be performed by an occasional assistant, and it becomes more economical to place upon the train a responsible person, who regulates the movements of the train and collects fares, &c., and to place subordinate servants, if any, at the stations; rather than, as is the case in this country, to place responsible persons at the stations, and subordinate servants on the trains.

The practice of allowing only one class of passengers, due to the democratic tendencies of the people, renders it necessary that there should be some recognized responsible person in a train to maintain order and prevent the oppression of the weak by the strong.

It appears to be from these causes that the practice, universal in America, has grown up of placing a train in charge of a "*conductor*," who, like the captain of a ship, has full control over its movements, exercises a kind of police over the passengers, and is the guardian of ladies or children travelling alone. This person could not, however, discharge his duties unless he had the power of moving from one part of the train to another. He has under his orders the engine-driver and fireman, a baggage-man, to whom is entrusted the duty of receiving, classifying, and giving out the baggage of the passengers, and one breaksman to every two cars. With freight trains the conductor has under his orders three or four breaksmen. This staff of servants is much larger than is furnished on trains on English railways, but it has, probably, been found necessary to send sufficient assistance with a train to meet cases of accident, and to be at hand to assist in maintaining order if necessary.

The large majority of lines in America are single, and the complications which arise in working them are mainly due to the unpunctuality of trains timed to meet one another. The usual system of working is as follows:—

The trains are all arranged to run to a time table, with a copy of which each conductor is furnished. So long as the train adheres to this time table all other trains are bound to keep out of its way.*

* In the case of freight trains, when the amount of freight to be conveyed is more than one engine can draw, a second, or even a third train is despatched after the first at an interval of probably a quarter of an hour; all these trains being considered to be parts of the *one* train, and under the control of the same conductor.

If the train fails to adhere to the time table, the train due to meet it, after waiting a specified time—on some lines a quarter of an hour, on some lines half an hour or an hour—proceeds as if nothing were amiss, the other trains being then bound to keep out of its way. The system on one or two lines was, that, when late, both trains should proceed at a slow pace until they meet, when the train nearest to a station should back to allow the other to pass. Occasionally trains of an inferior class are started to find their way between the regular trains.

It will easily be perceived that, under such a system, the duties of the conductors may, in some cases, involve calculations of which they scarcely possess the elements; and when the traffic is large, as for instance sixteen to twenty trains in twenty-four hours, the unpunctuality of one train must so delay the whole traffic as to entail serious loss of time and consequent expense.

It is extraordinary that considering the use made of it for other purposes, the Electric Telegraph has not been more largely resorted to for assisting in the working of American Railways. It is, however, in use on a few lines under two systems which I now propose to describe.

The Morse instrument is the one invariably used, the message being recorded on a slip of paper, or, if the operator prefers it, read by sound. A special wire is reserved for the purposes of the trains.

The first system is as follows: at each station there is a telegraphic instrument in connexion with the line wire allotted to a certain district.

Each time a train passes any station, the name of the train and the time of its passing the station is telegraphed. As the wire passes through every instrument in the district, this message is read by every station clerk, and is entered by each into a book.

It is the duty of the conductor of a train to keep himself well informed, by means of this book at each station, of the position of all the trains which have any influence over the movements of his train. And if either of two trains, timed to meet at a particular station, is late, the conductors of the two trains should make arrangements by telegraph for a meeting place different from that specified in the time

table. This system is in use on some of the Canadian Railways. It leaves with the conductors of the trains the responsibility of making arrangements at variance with the time table.

The second system places the responsibility of altering the time table, when circumstances render it necessary, upon an officer who is acquainted with the movements of the trains over the whole line, or the particular section of it committed to his charge. This system is as follows :—The line is divided into as many sections as the requirements of the traffic render necessary; upon each section, in some convenient situation, is placed an officer, called a "Train Despatcher," to whom is telegraphed the time at which every train arrives at, departs from, or passes each station.

Thus the train despatcher has continually before him the position of every train on the line, which he lays down upon a diagram board prepared for the purpose.

So long as the trains are working in accordance with the time table, this officer does not interfere; but when he observes that a train is delayed so much that it will interfere with the movements of some other train, he sends a message, distinctly expressed, through, the clerks at the nearest available stations, to the engine drivers and conductors of both trains, to alter the place of passing fixed in the time table; thus furnishing them with a revised time table. The message sent by the train despatcher is followed by the signal, "How do you understand this?" and the order is not to be obeyed until the train despatcher has signalled back to say that the conductor's version is correct.

The train despatcher is thus enabled to prevent the useless delay of trains, and to compensate for the impediments arising from the variations of weather, and other accidental circumstances, which prevent a time table from being rigidly adhered to. If from any cause he fails to send a message, the only result is that the trains are delayed to the same extent as would have been the case if there had been no telegraph.

This system might be applied with advantage on double lines of railway, to regulate the movements of trains, and prevent delays on

lines where a large mixed traffic is carried on; as, for instance, where fast passengertrains; or special cattle trains, are timed to pass slow trains, when ignorance of the position of a train often causes great delay and consequent expense, and also increases the chances of accident. On lines where the electric telegraph is in use, the clocks at all stations are regulated daily by it at noon.

The electric telegraph is also used on some railways to notify daily, at a particular time, the number and description of cars lying at each station, as well as the number required for moving the freight from each station, and orders for distributing the cars according to the requirements of the traffic are then forwarded by telegraph.

This system of telegraphic working, more perfect than any I have seen elsewhere, was first introduced by Mr. M'Callum, the Superintendent of the New York and Erie Railway.

This railway possesses very inferior gradients to the New York Central Railway, with which it is in competition for western traffic; and Mr. M'Callum has introduced a very careful system of working, by which it is enabled to compete successfully with its rival.

As the system, taken as a whole, presents many features of interest, and exhibits a high degree of centralization in the working, I shall endeavour briefly to describe it.

It may be premised that the New York and Erie Railway, with its subsidiary lines, is above 550 miles in length, extending from New York to Dunkirk, Buffalo, and Niagara. It possesses 168 miles of double line, and 387 miles of single line. The gross receipts per mile were 2,316*l.* for 1855. This amount of traffic is about the same as that on the Eastern Counties Railways in this country for the same period.

The idea upon which the system is founded is, that to work a line efficiently the responsible head must possess a complete daily history of the details of working in all their minutiæ; and the following general principles are laid down to carry it into effect.*

* These extracts are from a report made by Mr. M'Callum to the Directors of the New York and Erie Railroad, dated 25th March 1856.

" 1. A proper divison of responsibilities.

" 2. Sufficient power conferred to enable the same to be fully carried out, " that such responsibilities may be real in their character.

" 3. The means of knowing whether such responsibilities are faithfully " executed.

" 4. Great promptness in the report of all derelictions of duty, that evils " may be at once corrected.

" 5. Such information to be obtain through a system of daily reports and " checks, that will not embarrass principal officers, nor lessen their influence " with their subordinates.

" 6. The adoption of a system as a whole, which will not only enable the " general superintendent to detect errors imediatly, but will also point out the " delinquent."

The general superintendent is solely responsible to the president of the line; the organization under the general superintendent being as follows:

" 1. Division and branch superintendents.
" 2. Masters of engine and car repairs.
" 3. Car inspectors.
" 4. General freight agent.
" 5. General ticket agent.
" 6. General wood agent.
" 7. Superintendent of telegraph.
" 8. Foreman of bridge repairs.

" 1. The several divisions and branches are in charge of superintendents, " who are held responsible for the successful working of their respective divi- " sions, and for the maintenance of proper discipline and conduct of all per- " sons employed thereon, except such as are in the employment of other offices " acting under directions from the general superintendent's office, as herein- " after stated. They possess all the powers delegated by the organization to " the general superintendent, except in matters pertaining to the duties of " general ticket agent, general freight agent, general wood agent, telegraph " management, and engine and car repairs.

" They have authority to change, by telegraph or otherwise, the move-
" ment of trains from the times specified in the tables.

" 2. Masters of engine repairs are held responsible for the good condition
" of the engines and machinery in shops, and the cost of their repairs.

" It is their duty to make frequent and through inspection of the engines,
" so as to guard them from accidents and injuries which may result from the
" want of seasonable and trifling renewals: also to see that the engines are
" otherwise in efficient condition for use. They are also required to report to
" the Division Superintendents all cases they may discover of abuse or mal-
" treatment of locomotives by engineers or dispatchers.

" There are eight principal engine repair shops on the line, and five
" shops secondary in their character, in charge of foremen, which are used
" only for making such repairs as are required to enable engines to be run
" back to the principal shops, where all extensive repairs are made.

" 3. Car inspectors.— For the more thorough supervision of cars while in
" transit, the road is separated into two divisions, and a car inspector appoint-
" ed for each, whose duty it is to examine both passenger and freight cars, to
" see that they are kept in good condition, having special regard to the reduc-
" tion of *friction*, making all such trifling repairs as may be found necessary,
" and which can be performed, without the aid of the force employed in shops.
" Cars are inspected on entering each division by the division inspectors and
" their subordinates, who are authorized and required to condemn all cars
" which in their judgment are unsafe, and to call the attention of the officers
" in charge of general repairs to the fact.

" 4. The general freight agent has the supervision of the freight charges;
" his duties are, with the approval of the president or general superintendent,
" to make and regulate prices for the transportation of freight, to negotiate
" contracts and arrangements with individuals and other companies, and to
" see that such contracts are fairly and equitably complied with; also to in-
" vestigate and examine all claims for damages and losses of freight or baggage,
" and certify such of them as are found valid to the general superintendent
" for approval.

" 5. The general ticket agent is required, with the approval of the pre-
" sident or general superintendent, to regulate the prices, for transportation

" of passengers, to negotiate ticket arrangements with other companies, and
" to supervise all matters connected with the sale of tickets.

" 6. The general wood agent is required to provide the necessary supply
" of fuel for use on the road, to have it delivered in such quantities and of
" such qualities as shall be in accordance with the specifications; to see that
" it is carefully measured before payment is made, and to submit all contracts
" to the general superintendent for approval. At the end of each month it is
" his duty to furnish an accurate statement of all the fuel consumed during the
" month, and at the end of each quarter he is required to make a correct in-
" ventory of all the fuel received during the quarter, the amount paid for the
" same, the amount consumed, and the fuel on hand stating the locality of
" the same.

" 7. The superintendent of telegraphs is held responsible for the proper
" working and economy of the line, and prompt transmission of communica-
" tions; he is required to perfect such arrangements as well enable superin-
" tendents of divisions and other officers of the company to avail themselves,
" to the fullest extent, of the advantages to be derived from the use of the
" telegraph in communicating information or directions in regard to the move-
" ment of trains or business operations of the road, and to see that the instru-
" ments, batteries, and other property in his charge are kept in good order
" and preservation.

" 8. The foreman of bridge repairs has general charge of all the bridges
" upon the road; he is required to examine then frequently, and is held res-
" ponsible for their safety.

" Each officer possesses all the power necessary to render his position
" efficient, and has authority, with the approval of the president and general
" superintendent, to appoint all persons for whose acts he is held responsible,
" and may dismiss any subordinate when in his judgment the interests of the
" company will be promoted thereby.

" The enforcement of a rigid system of discipline in the government of
" works of great magnitude is indispensable to success. All subordinates
" should be accountable to *and be directed by their immediate superiors only*, as
" obedience cannot be enforced where the foreman in immediate charge is in-
" terfered with by a superior officer giving orders directly to his subordinates.

" It is very important, however, that principal officers should be in " possession of all the information necessary to enable them to judge correctly " as to the industry and efficiency of subordinates of every grade."

One peculiar feature of this sub-division of duties, as distinguished from the arrangements adopted on railways in this country, is, that the engines, when not in the shops for repair, are under the sole control of the division superintendent, who is responsible for obtaining a maximum of work from them; the masters of engine repairs being held responsible for frequently inspecting the engines, and taking care that they are not run when in need of repair.

The object of this organization being to obtain the greatest efficiency and economy in working the trains, the following are the general arrangements by which it is effected :—

1st. The electric telegraph is applied in the manner already described for preventing the delay and danger which would arise from the unpunctuality of a train, upon the movement of which other trains depend; and for regulating the movements of the cars in accordance with the requirements of the stations; by which means the rolling stock is utilized to the greatest extent possible.

2nd. The position of the trains is reported hourly by telegraph to the general superintendent's office. When passenger trains are more than ten minutes, and freight trains more than half an hour late, a special report of the cause of delay is made by the conductor at the nearest station, and forwarded to the general superintendent by telegraph. The information thus received, is tabulated on a convenient form, and further inquiries made, if necessary. This close investigation of delays is adopted, because they develope a class of facts and delinquencies which could not easily be detected in any other way; and when the prevailing causes of delays are known they can be removed.

The speed of freight trains is regulated at the lowest standard consistent with the exigencies of business; and the speed of the trains between stations is carefully checked in the office, and explanations called for if it has been exceeded. The necessary information is obtain-

ed from the daily reports of the conductors, engine-drivers, and station agents.

3rd. The work done by each engine and car is noted every day; a printed tabular statement, showing the load which each engine is capable of moving under specified circumstances of speed and weather, is furnished to the engine-driver, and the division superintendents are held responsible for seeing that the engines are worked up to their capacity, and that the useful load conveyed in the cars is a maximum.

A monthly statement of the number of miles run by each engine, of the expenses of running, of the cost of repairs, and of the work done by the engine, is printed and circulated amongst the servants of the company.

Each division superintendent furnishes to the general superintendent a monthly account for each train run during the month, showing the number of miles run by the trains,* and by each class of vehicle, the cost of fuel, oil, &c., the expenses of train attendants, and a proportion of the cost of station expenses, maintenance of way, &c., and all other expenses under the supervision of the division superintendent; as also the receipts from each train.

The returns required are framed with the view of obtaining a comparison between the management in the different divisions, and of the care which is bestowed on the working by the servants, as well as to show whether the receipts from each class of traffic are profitable.

The whole system is based upon a principle which seems to be one well adapted to secure economy and efficiency, viz., the maintenance of rigid discipline, and such a distribution of duties as will secure *personal accountability* through every grade of the service.

The speed of passenger trains in the Eastern States is not very different from that upon English railways, but the number of trains by which passengers can travel is much more limited. In the Western

* When the amount of traffic renders it necessary to run a special train, the receipts and expenses of the special train are credited to the regular train which it relieves.

States the speed is generally limited to about twenty or twenty-four miles per hour; certainty of communication being of far more consequence than speed, or frequency, in a new country.

Pages 25 *to* 27.

General Remarks.

There are two distinguishing features of the American system in its relations to the public, which contrast strongly with the system in operation in this country, viz:—

First. That the public are left almost entirly to take care of themselves in trains, at stations, and at level crossings, the only warning of danger being a placarded notice, or the sound of the engine bell.

Secondly. That the conveniences and comfort in the cars are extended equally to all ranks of passengers at a low rate of fare; by which the tendency to travelling is promoted.

These two features are no doubt in some measure due to the habits of the people, Indeed, it is to be borne in mind, that the American Railway System must not be judged by the standard that we have established in England.

In this country, where the space is limited, and where good roads and canals already existed, railways were sought as a means of annihilating distance by high speeds, and of centralizing business into one focus; and were at first scarcely considered as a means of conveyance for the lower classes.

In a new country, where time is not so valuable, high speeds are not required, but a cheap and certain means of locomotion for all classes, and of transporting the produce of the country to a market, is a first necessity. A railway is the best instrument for satisfying this want. Any saving in the cost per mile of a railway adds to the means available for extension; and, in a rapidly developing new country, capital is dear. Hence a rough and ready cheap railway, although it

entails increased cost for maintenance, is preferable to a more finished and expensive line. These considerations have influenced the construction of American railways, and the system which has grown up under them is well adapted to the wants of the country.

But this system has not yet attained a fixed position.

As the population and the consequent traffic increases, new capital must be expended in stations, sidings, and additional lines of rails, by which the cost per mile, which now averages from 7,000*l.* to 9,000*l.*, will be increased; the several railways will become more interlaced; a freer interchange of working stock will probably be necessary, possibly involving a resort to an establishment similar to the railway clearing house.

Independently of the conveniences afforded equally to all ranks of passengers, already mentioned, there are, many points in the system, which are worthy of consideration:—

1st. The general system upon which the railway companies are organized is one which appears to afford a good guarantee for efficient management. A railway is managed by a well-paid president, in whom the whole executive power is vested; he is responsible for the efficient and economical working of the line. A body of directors, generally good men of business, unpaid, excepting on peculiar occasions, are appointed to watch over the interests of the shareholders, and to see that the president does *his* duty; and also to take care that the accounts are kept in such a form, and with such checks, that malversation cannot take place. The shareholders have the privilege of electing the president and the directors annually, instead of being compelled to elect them for three years, as is the case in England. They, therefore, possess a direct control over the management of their affairs.

2nd. There are several matters, connected with the construction of railways, which are worthy of notice, viz:—

The encouragement of the use of rails on roads and streets, to facilitate the distribution of goods traffic, as well as to accomodate local

passenger traffic, would prove very useful in many towns, where the streets are broad, instead of throwing every impediment in the way of thus extending the advantages of railways.

The practice of attaching a signal to the lever by which the switches or points are moved, and of habitually locking facing points in position, might be advantageously followed.

The plan of carrying a railway over a hill by zig-zags would afford a comparatively inexpensive means of crossing a steep mountain pass. Each zig-zag terminates in a level space, and the train having been moved forward along one zig-zag on to the level space, is backed up the next, and so on.

The principle of supporting engines and csrriages on two independent trucks deserves attention;* the small diameter of wheels may possibly increase the friction, but the cars run safely, and the double springs secure easy motion; it enables very long-bodied cars to be used, which accommodate more passengers with less dead weight than is usually the case in England; especially on narrow gauge lines. The absence of doors renders the amount of attendance on passengers more easy. The conveniences, before described, which are afforded in American cars, are a great comfort on long journeys.

The invariable establishment of a means of communication between the different servants in charge of a train, and the use of breaks to each carriage, might be adopted with advantage. The mode of coupling carriages together by means of a central connection deserves notice, as being less dangerous for the *employés* than the plan in use on English railways.†

The protection afforded to the engine driver and fireman against the inclemency of the weather is well worthy of imitation, and would promote safety by enabling the men to keep a better look out. And

* Carriages on this principle were in use for a short time on the Waterford and Limerick Railway.

† A central connexion between carriages has been in use on the Dublin and Kingstown Railway.

the use of a bell on the engine, in lieu of the continual use of the steam whistle, to give notice of the approach of a train to stations and at level crossings, pressents many advantages, especially in towns.

3rd. Economy and increased efficiency results from the use of the electric telegraph to transmit information of the movements of all the trains on a railway, and to enable a responsible officer, placed in a central position, to control them when they become irregular, as well as to learn each day the positions of all cars on the railway, and the quantity of goods, &c. at each station which requires to be accommodated, and to give orders for the cars to be moved to meet the wants of the traffic.

4th. The detailed organization on the New York and Erie Railway deserves attentive consideration; its main features being a high degree of centralization, and the systematic arrangement of the duties of the officers and servants, so as to enforce a rigid system of personal accountability through every grade of the service.

5th. Those general legislative provisions for securing the public interests, which appear principally to deserve notice, are that the railway companies shall keep their lines in repair and open for public use, and that they shall supply sufficient accommodation, and transport merchandise and property without partiality, favour, or affection, and with all practicable dispatch. That a railway company is prohibited from exercising the calling of a banker, broker, or dealer in any article whatever. That in some States a government department is empowered to inquire minutly into the causes of railway accidents, to examine witnesses on oath, and to call for all necessary books, papers, &c. and to publish their reports.

6th. But it is with reference to the construction of railways in our own colonies that the American system deserves especial notice. The considerations which led to the adoption of, and the necessities which fostered, that system apply with equal force to railways in the colonies. It appears, therefore, desirable to call attention to some of the deductions which may be drawn from the consideration of this system.

a. A railway would appear to be the best road for arterial lines of communication in a new country.

b. In making railways in a new country, bearing in mind the high rate of interest which money commands, the outlay for construction should be as small as possible consistent with safety and economy of working; the object being to devote the money, to be spent, to extending the mileage and opening out the country, rather than to making very solid works or to obtaining high speeds.

c. Railways made by the States in America have not proved successful, in consequence of the persons selected to manage them being chosen for political considerations.

d. The encouragement given to private companies for the construction of railways in new states, by means of grants of land, has proved very successful. It has facilitated the rapid settlement of the country and the development of its resources. It has directly benefited the State by enhancing the price of the land retained by the State, as well as by the permanent reduction of the general taxation occasioned by the contribution of seven per cent. on the gross receipts of the railway reserved to the State in consideration of the grant of land. But the successful instances of this system are limited to localities where land is of a superior quality, and the climate favourable.

I cannot close this report without expressing to your Lordships how much I am indebted for the information which I have obtained, to the invariable courtesy that I received from every person connected with railways in the United States and Canada, and to the great readiness with which they furnished me with all the particulars in their power.

I have the honor to be, &c.

DOUGLAS GALTON,

Captain, Royal Engineer.

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